ANNUAL REPORT

OF THE

BOARD OF REGENTS

OF THE

SMITHSONIAN INSTITUTION,

SHOWING

THE OPERATIONS, EXPENDITURES, AND CONDITION
OF THE INSTITUTION

TO

JULY, 1895.

Given by
Smithsonian Inst.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1896.

LETTER

FROM THE

SECRETARY OF THE SMITHSONIAN INSTITUTION,

ACCOMPANYING

The annual report of the Board of Regents of the Institution for the year ending June 30, 1895.

SMITHSONIAN INSTITUTION,
Washington, D. C., July 1, 1895.

To the Congress of the United States:

In accordance with section 5593 of the Revised Statutes of the United States, I have the honor, in behalf of the Board of Regents, to submit to Congress the annual report of the operations, expenditures, and condition of the Smithsonian Institution for the year ending June 30, 1895.

I have the honor to be, very respectfully, your obedient servant,

S. P. LANGLEY,
Secretary of Smithsonian Institution.

Hon. ADLAI E. STEVENSON,
President of the Senate.

ANNUAL REPORT OF THE SMITHSONIAN INSTITUTION FOR THE YEAR ENDING JUNE 30, 1895.

SUBJECTS.

1. Proceedings of the Board of Regents for the session of January, 1895.

2. Report of the Executive Committee, exhibiting the financial affairs of the Institution, including a statement of the Smithson fund, and receipts and expenditures for the year ending June 30, 1895.

3. Annual report of the Secretary, giving an account of the operations and condition of the Institution for the year ending June 30, 1895, with statistics of exchanges, etc.

4. General appendix, comprising a selection of miscellaneous memoirs of interest to collaborators and correspondents of the Institution, teachers, and others engaged in the promotion of knowledge. These memoirs relate chiefly to the calendar year 1895.

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THE SMITHSONIAN INSTITUTION.

MEMBERS EX OFFICIO OF THE "ESTABLISHMENT."

(January, 1895.)

GROVER CLEVELAND, President of the United States.
ADLAI E. STEVENSON, Vice-President of the United States.
MELVILLE W. FULLER, Chief Justice of the Supreme Court of the United States.
WALTER Q. GRESHAM Secretary of State.
JOHN G. CARLISLE, Secretary of the Treasury.
DANIEL S. LAMONT, Secretary of War.
RICHARD OLNEY, Attorney-General.
WILSON S. BISSELL, Postmaster-General.
HILARY A. HERBERT, Secretary of the Navy.
HOKE SMITH, Secretary of the Interior.
J. STERLING MORTON, Secretary of Agriculture.

REGENTS OF THE INSTITUTION.

(List given on the following page.)

OFFICERS OF THE INSTITUTION.

SAMUEL P. LANGLEY, *Secretary.*

Director of the Institution and of the U. S. National Museum.

G. BROWN GOODE, *Assistant Secretary.*

REGENTS OF THE SMITHSONIAN INSTITUTION.

By the organizing act approved August 10, 1846 (Revised Statutes, Title LXXIII, section 5580), and amended March 12, 1894, "The business of the Institution shall be conducted at the city of Washington by a Board of Regents, named the Regents of the Smithsonian Institution, to be composed of the Vice-President, the Chief Justice of the United States, three members of the Senate, and three members of the House of Representatives, together with six other persons, other than Members of Congress, two of whom shall be resident in the city of Washington and the other four shall be inhabitants of some State, but no two of the same State."

REGENTS FOR THE YEAR ENDING JUNE 30, 1895.

The Chief Justice of the United States:
- MELVILLE W. FULLER, elected Chancellor and President of the Board January 9, 1889.

The Vice-President of the United States:
- ADLAI E. STEVENSON.

United States Senators: Term expires.
- JUSTIN S. MORRILL (appointed Feb. 21, 1883, Mar. 23, 1885, and Dec. 15, 1891) .... Mar. 3, 1897
- SHELBY M. CULLOM (appointed Mar. 23, 1885, and Mar. 28, 1889) .Mar. 3, 1895
- GEORGE GRAY (appointed Dec. 20, 1892, and Mar. 20, 1893) .... Mar. 3, 1899

Members of the House of Representatives:
- JOSEPH WHEELER (appointed Jan. 10, 1888, Jan. 6, 1890, Jan. 15, 1892, and Jan. 4, 1894) .... Dec. 25, 1895
- ROBERT R. HITT (appointed Aug. 11, 1893, and Jan. 4, 1894) ...... Dec. 25, 1895
- W. C. P. BRECKINRIDGE (appointed Jan. 15, 1892, and Jan. 4, 1894) .... Dec. 25, 1895

Citizens of a State:
- HENRY COPPÉE, of Pennsylvania (appointed Jan. 19, 1874, Dec. 19, 1879, Dec. 26, 1885, and Jan. 26, 1892. Died Mar. 21, 1895).
- JAMES B. ANGELL, of Michigan (appointed Jan. 19, 1887; Jan. 9, 1893) .... Jan. 19, 1899
- ANDREW D. WHITE, of New York (appointed Feb. 15, 1888, and Mar. 19, 1894) .... Mar. 19, 1900
- WILLIAM PRESTON JOHNSTON, of Louisiana (appointed Jan. 26 1892) .... Jan. 26, 1898

Citizens of Washington:
- JAMES C. WELLING (appointed May 13, 1884, and May 22, 1890. Died Sept. 4, 1894).
- JOHN B. HENDERSON (appointed Jan. 26, 1892) .... Jan. 26, 1898
- GARDINER G. HUBBARD (appointed Feb. 27, 1895) .... Feb. 27, 1901

Executive Committee of the Board of Regents.

JAMES C. WELLING, *Chairman*. HENRY COPPÉE. J. B. HENDERSON.

JOURNAL OF PROCEEDINGS OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION.

ANNUAL MEETING OF THE BOARD OF REGENTS.

JANUARY 23, 1895.

In accordance with a resolution of the Board of Regents, adopted January 8, 1890, by which its stated annual meeting occurs on the fourth Wednesday in January, the Board met to-day at 10 o'clock a. m.

Present: The Chancellor (the Hon. M. W. Fuller) in the chair, the Hon. J. S. Morrill, the Hon. George Gray, the Hon. Joseph Wheeler, the Hon. R. R. Hitt, Dr. Henry Coppée, the Hon. J. B. Henderson, and the Secretary, Mr. S. P. Langley.

Excuses for nonattendance were read from Dr. William Preston Johnston, on account of illness; from the Hon. S. M. Cullom, on account of a domestic affliction, and from Dr. Andrew D. White, on account of absence in Europe.

At the Chancellor's suggestion, the Secretary read in abstract the minutes of the last meeting, which were approved.

The Secretary stated that the term of Dr. Andrew D. White as Regent of the Institution having expired on February 15, 1894, he was reappointed by joint resolution of Congress, approved by the President March 19, 1894.

The Secretary announced the death, on September 4, 1894, of Dr. Welling, chairman of the Executive Committee.

On motion, the Chancellor appointed Senator Henderson and the Secretary a committee to prepare suitable resolutions expressing the Board's sense of loss, and the committee presented the following:

Whereas the members of the Board of Regents of the Smithsonian Institution have been called upon to mourn the death of their esteemed colleague, the late James C. Welling, LL. D., president of the Columbian University, who has long been interested in the welfare of the Institution, and who for many years has been a Regent and chairman of its Executive Committee,

Resolved, That the Board of Regents feels deep regret in the loss of one whose long and distinguished career of public usefulness, especially in the promotion of institutions for higher education, commanded their respect, and whose personal character and unselfish devotion to the highest ideals of scholarship and citizenship, their sincere admiration.

Resolved, That in the death of President Welling the Smithsonian Institution has suffered the irreparable loss of an earnest friend, a wise and judicious counselor, and one who was preeminently an exponent of its time-honored policy; and the Board of Regents a friend and associate whom they valued most highly.

Resolved, That these resolutions be recorded in the Journal of the Proceedings of the Board, and that the Secretary be requested to send a copy of them to the family of their departed associate and friend, in token of sympathy in this common affliction.

Resolved, That the Secretary be requested to prepare a eulogy of President Welling for insertion in the Journal of the Board of Regents.

Dr. Coppée said that he had been longer associated with Dr. Welling than any other member of the Board, since 1884, and particularly as a member of the Executive Committee with him, and as he had for Dr. Welling a very high esteem, he thought it proper to say a word in this connection. Dr. Welling was one of the most valuable citizens of Washington, to whom was confided many trusts, among them the presidency of the Columbian University, and the chairmanship of the Executive Committee of this Institution, and he did well everything that was confided to him. He was a man pure in thought, honest in purpose and action, and intelligent in judgment. He held a ready pen, and how polished his public utterances were, all here would remember who had heard him when he presented papers and other matters before this Board.

Dr. Coppée added that Dr. Welling was cautioned by his friends that he worked too hard, and instanced the fact that at the last meeting which he attended, in May, he announced his purpose to write a work with reference to his favorite subject of anthropology, when Senator Henderson, now present, said to him: "The best thing that you can do is to consider one individual of the species of 'anthropos,' and very carefully, at this time. You are the 'man;' take care of yourself." It was a grave pleasantry. It was good counsel, but it came too late, for Dr. Welling was injured by the hard work that he did. In him is lost a man who was preeminently excellent in counsel, whether to the Board or in private, but he would leave it to the Secretary to speak of him further.

Senator Henderson spoke of his long and intimate acquaintance with Dr. Welling and expressed his admiration for him as a citizen and as an officer of the Institution.

The Secretary then said:

I have lost in Dr. Welling a personal friend, but I only have to speak of him now in his relationship to this Institution—an institution whose conservative character has been partly due to good fortune in the presence and advice of such men.

Dr. Welling was one who possessed, beyond anyone else, what may be called the traditions of the Institution; and though these were not of course his exclusive property, in this respect, as in others, his loss can not be supplied.

The rules of conduct which have been laid down by the Regents and by the Secretaries who have administered them are not so much derived from *a priori* views as they are the outgrowth of accumulated experience; and this experience, it has been thought, is in part, perhaps, due to the exceptionally long incumbencies of members of the Board as compared with ordinary tenures of office here, and to the continuity of the knowledge of its activities, as illustrated in the case of this departed friend.

James Clark Welling, at the time of his death, September 4, 1894, was nearly 70 years of age. Descended from New England colonial ancestors, a native of one of

the Middle States,[1] in early manhood a teacher in the South, and for nearly half a century a resident of the national capital, he was an American of the noblest type, free from sectional bias, personifying the best traits and tendencies of the nation, loyal to the traditions and aspirations of its founders.

He was graduated in 1844 from the College of New Jersey, studied law, and was admitted to the bar, but soon afterwards entered upon the profession of journalism. He always retained, however, a strong inclination for the study of constitutional and international law, and of politics, and his interest in public affairs was greatly stimulated by his connection for fifteen years with the most important of Washington journals, at that time national in its influence. He became the literary editor of the National Intelligencer in 1850, and was its managing editor throughout the entire period of the civil war. In this capacity he had the privilege of personal acquaintance with all our public men, and confidential access to many of them, including Lincoln, Seward, and Stanton.

In later life his attention was given chiefly to educational work. For a time president of St. John's College, Maryland, and later professor of belles-lettres at Princeton, he was, in 1870, recalled to Washington to become president of the Columbian University, an institution founded fifty years before, in the hope that it might fulfill the desire of Washington, Barlow, and Adams, that a seat of liberal learning should exist at the capital. Dr. Welling was led to accept this position by the urgency of the philanthropist Corcoran and the advice of Henry, both of whom were influenced by the hope of having with them one of the founders of a national university, and who believed that a man of Dr. Welling's character would find in such a position a wide field of influence.

His aspirations for the university were never fully realized, owing to the impossibility of securing endowments from private sources for a public institution located so near to the seat of government. He nevertheless secured a considerable addition to its endowment, added new professional schools, greatly increased the number of its faculty and students, removed the institution from the suburbs to a new building in the heart of the city, and accomplished many other things which seemed really wonderful in view of the smallness of the resources at his command. The dream of his life was to establish a school of comparative jurisprudence—the only one of its kind in the world—as a branch of the university. In 1892 he visited Europe, secured approval of his plans from Sir Frederick Pollock and other eminent jurists, and their promise to come to America to lecture as members of the faculty. Failing health interfered with the realization of his plan, which I can but believe he would have otherwise forced into success.

After his resignation of the presidency in 1893, he still retained the chair of international law and the position of dean of the university law school, and, full of hopefulness, it was his purpose to labor on for his beloved project. He confidently expected to live to be 80, and to devote the remaining ten years of his life to the compilation of a political history of the civil war, a work for which no one was so well qualified by experience, knowledge, and critical skill as himself. He was a representative man in Washington, identified with all interests which tend toward good citizenship, and held many positions of public trust and honor. He was president of the board of trustees of the Corcoran Art Gallery and of the American Copyright League, and was appointed by President Harrison commissioner to the Columbian Historical Exposition at Madrid in 1892. His bearing was that of a courteous gentleman of the old school. His scholarship was accurate, broad, and genial, as was shown by the critical reviews which he contributed during his later years to some of the principal American journals. His favorite study in hours of relaxation was that of the sacred poetry of the early Christian Church, some of which he had translated, though not for publication.

In 1884 he was chosen a Regent of this Institution to succeed the Reverend Dr. Parker. For ten years he gave conscientious attention to its interests, and upheld

[1] He was born in Trenton, July 14, 1825.

in every way those conservative and dignified traditions of which I have already spoken of him as almost the living embodiment; and while he did this primarily because of their harmony with his own personal tendencies and convictions as to their value, he did so because of his affection and reverence for the first Secretary, Joseph Henry, whose pupil he had been in his youth, and with whom in middle life he maintained the relation of friend and confidant. After Henry's death, Dr. Welling consented to add to his already burdensome duties those of the chairman of the Executive Committee, which he performed till his own death, so that he may be said to have been a link between the past and present in the history of this Institution, though happily not the only one, since it has preserved others in his contemporaries.

On motion, the resolutions were unanimously adopted by a standing vote.

The Secretary then presented his printed annual report to June 30, 1894, and recalled to the Regents the fact that by act of Congress, approved by the President March 12, 1894, section 5579 of the Revised Statutes was amended to read as follows:

That the President, the Vice-President, the Chief Justice, and the heads of Executive Departments are hereby constituted an establishment by the name of the Smithsonian Institution for the increase and diffusion of knowledge among men, and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions hereinafter contained, and no other.

As now organized, the Smithsonian Establishment consists of the following ex officio members:

GROVER CLEVELAND, President of the United States.
ADLAI E. STEVENSON, Vice-President of the United States.
MELVILLE W. FULLER, Chief Justice of the United States.
WALTER Q. GRESHAM, Secretary of State.
JOHN G. CARLISLE, Secretary of the Treasury.
DANIEL S. LAMONT, Secretary of War.
RICHARD OLNEY, Attorney-General.
WILSON S. BISSELL, Postmaster-General.
HILARY A. HERBERT, Secretary of the Navy.
HOKE SMITH, Secretary of the Interior.
J. STERLING MORTON, Secretary of Agriculture.

By the same act section 5591 was amended as follows:

The Secretary of the Treasury is authorized and directed to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may, from time to time, see fit to deposit, not exceeding, with the original bequest, the sum of $1,000,000.

Provided, That this shall not operate as a limitation on the power of the Smithsonian Institution to receive money or other property by gift, bequest, or devise, and to hold and dispose of the same in promotion of the purposes thereof.

The Secretary added that what he had otherwise said in the report before the Board might almost be summarized in the statement that the past year had been, in many respects, perhaps the busiest that the Institution had ever known; and this both in the field of its ordinary activities and in new ones.

The progress of the Museum had been very considerable, the collections were never in better condition, and the contributions to science derived from their study had been of more than usual extent and value.

The buildings had been visited by 200,000 persons during the past year, and a very large number of specimens, accurately named and labeled, have been sent out to other museums and institutions throughout the United States. It should be said, however, that those who are interested in the Museum see with a feeling of real distress that, with all that it is doing, it is compelled to come short of its functions as a national institution, from the fact that such large collections of material gathered on the North American continent are being carried abroad for the want of means to retain them at home, and that desirable collections in every other field are constantly slipping out of our grasp. European museums have spent during the last year hundreds of thousands of dollars in availing themselves of the fast diminishing opportunities for making collections of material objects representing the work of the primitive races of this continent, while the entire sum of money available here for this purpose has been $3,725. Notwithstanding the great opportunities offered at the close of the Chicago Exposition, within the past year the new Field Columbian Museum had expended probably more than $500,000 in the purchase of collections, and the American Museum of Natural History in New York not less than $100,000.

The Secretary went on to say that he need hardly recall that the Zoological Park, as originally sanctioned by the Regents, was a national and not a local measure. It was to be a great preserve of certain animal races of the continent—like, for instance, the buffalo—and was to do work which, for reasons already explained, the great national parks of the West could not do so well. This was to be its primary function, and recreation a subordinate one. Indirectly, if not through formal legislation, the direction in which the park is tending is more that of the ordinary zoological garden, where entertainment is a principal feature, than in that of the primary object. In spite of this the park has preserved, as far as it can, the lines of the original purpose. The buffalo, for example, are breeding in captivity in a way only possible in such paddocks as can be provided in this large reserve, while others of the great races are being sheltered, and the park is, though in a limited measure, filling its place as a city of refuge for these vanishing animal peoples. The Regents will be glad to know that a secondary legitimate object of the gardens is being most amply filled, for, to use a common expression, it is becoming like "the lungs of the city," since, from its position, it is accessible to the poor as well as to the rich, and is for the health and recreation of every citizen; and he would mention in striking evidence of the public appreciation of this most important feature, and as an evidence that the Regents' large intent has not wholly failed of its purpose, that the park, even in its inchoate condition, has been visited by as many as 30,000 people in a single day.

The Secretary continued that the work of the Bureau of Ethnology lies largely in collecting and preserving material for the study of the

languages of the Indian tribes of the continent, upon which all conclusions as to their origin and relationship so closely depend; and in that respect the Bureau had done its usual valuable service. He had authorized the sending out, on its own account, minor expeditions for collecting records of the vanishing aboriginal races and for the study of the peculiar customs among the last of the really savage tribes of our borders, and important results had been obtained, such, for instance, as in a recent expedition to the home of the Papagos and Seri Indians.

The Secretary called the attention of the Regents to the growing activities and consequent increased labor in the Bureau of International Exchanges. There are something like 24,000 correspondents scattered over the world, and its usefulness has never been greater. These correspondents are partly indicated on the map inserted in the report, which strikingly shows their world-wide distribution, where it will be noticed that the occurrence of the red dots is about proportional to the spread of civilization, and where a glance shows that a comparison of Spain and France, of China and Japan, in education, may be inferred from their relationships to the Institution alone.

In regard to the Astrophysical Observatory, the Secretary remarked that he had said less because it was something in which he had a strong personal interest, and perhaps a personal bias; but under this correction he might observe that there was probably no other such observatory in the world for just this purpose, or one whose work has had more gratifying recognition from all specialists in its own subject than this has in the last year.

He further said that he had left to the last the mention of the affairs of the parent Institution, and he desired at present to repeat that all the activities which had just been mentioned, and which were now supported by Government appropriations, were really carried on in part by the Smithsonian fund, for there was no appropriation to meet the general expenses of the Secretary's office, incident to the administration of the different Government appropriations with which the Institution was charged. He referred not only to the minor matters of clerical and messenger service, but to the responsibilities connected with the disbursement of Government funds and to the increasing burden of general administrative work that can not be delegated by the Secretary to an ordinary clerk, but calls for a much higher order of ability, and necessarily also for more liberal compensation. These expenses should not be borne by the Smithsonian fund, as they were, to a large extent, at present; nor were they properly chargeable to any one of the Government appropriations, but they were common to them all.

In connection with the Hodgkins fund, the Secretary said that he had already called the attention of the Regents to the fact that, in accordance with the wishes of Mr. Hodgkins, he had submitted to him before his death a plan for expending the income of the first two years

of the Hodgkins bequest largely in prizes of considerable amounts, which were intended to draw attention to the subject. He had also placed before the Regents a portion of the circulars which were sent all over the civilized world, on the part of the Institution, to this end, and he had taken occasion in the same connection to send a description of the Institution, written in various languages, which had been prepared after consultation with one of the Regents, and which some of them might care to see.

The result of this work had been the presentation of more than two hundred competitive works for the prizes, some of them from the most eminent men of science in Europe and America, and some from names comparatively unknown; and a committee—whose active members are Dr. G. Brown Goode, Assistant Secretary of this Institution, Deputy Surg. Gen. John S. Billings, U. S. A., and Prof. Mark W. Harrington, Chief of the Weather Bureau—was engaged in examining them.

It was expected that the European committee would be composed of Professors Huxley, Janssen, and Helmholtz, who had kindly consented to serve, but the death of the last-named eminent man of science has temporarily deferred its formation.

The Secretary added that he was not yet prepared to advise the Regents of the result of these competitions, further than to say that, incidentally to their main object, they had probably brought the work of the Institution before not only European men of science, but the world of action, as well as of study, more completely than any incident which had occurred at any time in its history. This interest was slow in awakening, but afterwards grew rapidly, so that the time for receiving the essays was extended to the close of 1894.

The Secretary considered that the system of prizes had now completed its best work in calling attention to the Institution and the fund it administered, as well as to its fitness as an administrator of other trusts of this character.

The Secretary continued that he had already advised the Regents that a bequest had been made to the Institution by a resident of Washington, Mr. Robert Stanton Avery, whose extremely feeble health at the time of the last Board meeting did not give hope that he would survive the year. Mr. Avery died on September 12, 1894. Owing to the general fall in prices, the amount coming from the estate is likely to be very much smaller than the testator supposed he was giving.

On motion, the report of the Secretary was accepted.

Dr. Coppée then said that by reason of the death of the chairman of the Executive Committee, it devolved upon him to present the report of that committee for the fiscal year ending June 30, 1894, which he did in printed form, and, on motion, the report was adopted.

Dr. Coppée then introduced the following resolution, which was adopted:

Resolved, That the income of the Institution for the fiscal year ending June 30, 1896, be appropriated for the service of the Institution, to be expended by the Secretary, with the advice of the Executive Committee, with full discretion on the part of the Secretary as to items.

The Secretary stated that in 1874 the Institution received $1,000 from the estate of James Hamilton, esq., of Carlisle, Pa., bequeathed in the following clause of his will:

I give $1,000 to the Board of Regents of the Smithsonian Institution, located at Washington, D. C., to be invested by said Regents in some safe fund, and the interest to be appropriated biennially by the Secretaries, either in money or a medal, for such contribution, paper, or lecture on any scientific or useful subject as said Secretaries may approve.

Under resolution of the Regents, the bequest was deposited in the Treasury on the same terms as the original Smithsonian bequest. In administering the trust the income has thus far been only partially used, the annual interest not being yet sufficient to bear the expense attendant on the designing and striking of a proper medal. The accrued interest on the fund having reached a sum more than equal to the original bequest, $1,000 of this interest might now be added to the principal, thus bringing the fund to $2,000, the interest on which would more properly carry out the purposes of the testator. The authority of the Regents was therefore requested for thus increasing the original bequest and for treating the $2,000 thereby created as the limit of a permanent fund to be called by the name of the donor, the interest to be administered under the terms of the resolution relative to income and expenditure.

Senator Henderson offered the following resolutions, explaining that their purpose was to add $1,000 of the $1,200 which had accumulated to the original bequest, which would make a fund of $2,000 and leave a balance of interest to its credit of $200:

Resolved, That the Secretary is hereby authorized to add to the bequest of $1,000 received from James Hamilton the accrued interest upon the said bequest to the amount of $1,000 and no more, the same to be deposited in the Treasury of the United States under the terms of section 5591 of the Revised Statutes.

Resolved, That the fund of $2,000 thus created be known as the "Hamilton fund," and that the income from this fund be administered by the Secretary under the terms of the resolution relative to income and expenditure.

On motion, the resolutions were adopted.

There being no further business to come before the Board, on motion, it adjourned.

REPORT OF THE EXECUTIVE COMMITTEE OF THE BOARD OF REGENTS OF THE SMITHSONIAN INSTITUTION

FOR THE YEAR ENDING JUNE 30, 1895.

To the Board of Regents of the Smithsonian Institution:

Your Executive Committee respectfully submits the following report in relation to the funds of the Institution, the appropriations by Congress, and the receipts and expenditures for the Smithsonian Institution, the U. S. National Museum, the International Exchanges, the Bureau of Ethnology, the National Zoological Park, and the Astrophysical Observatory for the year ending June 30, 1895, and balances of former years:

SMITHSONIAN INSTITUTION.

Condition of the fund July 1, 1895.

The amount of the bequest of James Smithson deposited in the Treasury of the United States, according to act of Congress of August 10, 1846, was $515,169. To this was added by authority of Congress, February 8, 1867, the residuary legacy of Smithson and savings from income and other sources, to the amount of $134,831.

To this also have been added a bequest from James Hamilton, of Pennsylvania, of $1,000; a bequest of Dr. Simeon Habel, of New York, of $500; the proceeds of the sale of Virginia bonds, $51,500; a gift from Thomas G. Hodgkins, of New York, of $200,000, and $8,000, being a portion of the residuary legacy of Thomas G. Hodgkins, and $1,000, the accumulated interest on the Hamilton bequest, making in all, as the permanent fund, $912,000.

The Institution also holds the additional sum of $42,000, received upon the death of Thomas G. Hodgkins, in registered West Shore Railroad 4 per cent bonds, which were, by order of this committee, under date of May 18, 1894, placed in the hands of the Secretary of the Institution, to be held by him subject to the conditions of said order.

Statement of the receipts and expenditures from July 1, 1894, to June 30, 1895.

RECEIPTS.

Cash on hand July 1, 1894		$59,598.50	
Interest on fund July 1, 1894	$27,143.92		
Interest on fund January 1, 1895	27,330.00		
		54,473.92	
Interest to January 1, 1895, on West Shore bonds		1,680.00	
			$115,752.42
Cash from sales of publications		254.59	
Cash from repayments, freight, etc		5,819.79	
			6,074.38
Total receipts			121,826.80

EXPENDITURES.

Building:			
Repairs, care, and improvements	$5,715.50		
Furniture and fixtures	518.05		
		$6,233.55	
General expenses:			
Meetings	192.25		
Postage and telegraph	394.38		
Stationery	819.97		
General printing	1,527.90		
Incidentals (fuel, gas, etc.)	4,653.72		
Library (books, periodicals)	2,177.88		
Salaries[1]	20,622.75		
Gallery of art	1,246.10		
		31,634.95	
Publications and researches:			
Smithsonian contributions	834.80		
Miscellaneous collections	5,165.71		
Reports	638.78		
Researches	6,071.60		
Apparatus	315.13		
Museum	331.40		
Hodgkins fund	1,806.52		
Explorations	700.00		
		15,863.94	
Literary and scientific exchanges		4,092.62	
Increase of fund		1,000.00	
			58,825.06
Balance unexpended June 30, 1895			63,001.74

The cash received from the sale of publications, from repayments for freights, etc., is to be credited to the items of expenditure, as follows:

Smithsonian contributions	$95.44	
Miscellaneous collections	157.67	
Reports	1.48	
		$254.59
Researches		9.43
Museum		131.40
Exchanges		5,660.88
Stationery		2.00
Incidentals		11.96
Postage		4.12
		6,074.38

[1] In addition to the above, $20,622.75, paid for salaries under general expenses, $9,357.88 was paid for services, viz, $2,059.34 charged to building account, $1,142.45 to Hodgkins fund account, $700.08 to library account, and $5,456.01 to researches account.

The net expenditures of the Institution for the year ending June 30, 1895, were therefore $52,750.68, or $6,074.38 less than the gross expenditures, $58,825.06, as above stated.

All moneys received by the Smithsonian Institution from interest, sales, refunding of moneys temporarily advanced, or otherwise, are deposited with the Treasurer of the United States to the credit of the Secretary of the Institution, and all payments are made by his checks on the Treasurer of the United States.

Your committee also presents the following statements in regard to appropriations and expenditures for objects intrusted by Congress to the care of the Smithsonian Institution:

INTERNATIONAL EXCHANGES.

Receipts.

Appropriated by Congress for the fiscal year ending June 30, 1895, "For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees" (sundry civil act, August 18, 1894)			$17,000.00

Expenditures from July 1, 1894, to June 30, 1895.

Salaries or compensation:			
1 curator, 12 months, at $225		2,700.00	
1 clerk, 12 months, at $120		1,440.00	
1 clerk, 12 months, at $160		1,920.00	
1 clerk, 12 months, at $75		900.00	
1 clerk, 12 months, at $75		900.00	
1 clerk, 12 months, at $85		1,020.00	
1 clerk, 12 months, at $80		960.00	
1 clerk, 12 months, at $65		780.00	
1 clerk, 10 months 22 days, at $45		481.93	
1 clerk, 2 months 6 days, at $50, 1 copyist, 87 days, at $1.50		240.18	
1 clerk, 1 month 12 days, at $60		83.23	
1 packer, 12 months, at $50		600.00	
1 laborer, 313 days, at $1.50		469.50	
1 agent, 12 months, at $50		600.00	
1 agent, 6 months, at $83.33⅓		500.00	
Total salaries or compensation		13,594.84	
General expenses:			
Freight	$1,849.91		
Packing boxes	791.28		
Printing	31.60		
Postage	260.00		
Stationery and supplies	470.36		
		3,403.15	
			16,997.99
Balance July 1, 1895			2.01

INTERNATIONAL EXCHANGES, 1894.

Balance as per last report, July 1, 1894	$25.42
Expenditures to June 30, 1895.	
Freight	$25.32
Balance	.10

INTERNATIONAL EXCHANGES, 1893.

Balance as per last report, July 1, 1894	$0.44

Balance carried, under the provisions of the Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund, June 30, 1895.

NORTH AMERICAN ETHNOLOGY.

Appropriation by Congress for the fiscal year ending June 30, 1895, "For continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of necessary employees, $40,000, of which sum not exceeding $1,000 may be used for rent of building" (sundry civil act, August 18, 1894)	$40,000.00
Balance July 1, 1894, as per last report	5,253.78
Total	45,253.78

The actual conduct of these investigations has been continued by the Secretary in the hands of Maj. J. W. Powell, Director of the Bureau of Ethnology.

Expenditures July 1, 1894, to June 30, 1895.

Salaries or compensation:	
1 Director, 12 months, at $375	$4,500.00
1 ethnologist in charge, 1 month, at $275; 3 months, at $250; 8 months, at $262.50	3,125.00
1 ethnologist, 1 month, at $250; 2 months 24 days, at $166.66	712.34
1 special ethnologist, 7 days, at $200 per month	45.16
1 ethnologist, 1 month, at $200; 10 months, at $166.66	1,866.60
1 ethnologist, 2 months 4 days, at $166.66; 5 months, at $141.66	1,065.42
1 ethnologist, 1 month, at $150; 3 months, at $125; 8 months, at $137.50	1,625.00
1 ethnologist, 1 month, at $150; 11 months, at $125	1,525.00
1 ethnologist, 1 month, at $150; 11 months, at $125	1,525.00
1 ethnologist, 1 month, at $133.33; 11 months, at $110	1,343.33
1 ethnologist, 1 month, at $110; 11 months, at $125	1,485.00
1 ethnologist, 12 months, at $100	1,200.00
1 archæologist, 10 months at $133.33	1,333.30
1 assistant archæologist, 10 months 15 days, at $100	1,050.00
1 stenographer, 1 month, at $133.33; 1 ethnologist, 3 months, at $125; 8 months, at $133.33	1,574.97
1 clerk, 3 months, at $100	300.00
1 clerk, 1 month, at $100; 11 months, at $83.33	1,016.63
1 clerk, 1 month, at $100; 6 months, at $75	550.00
1 clerk, 1 month, at $100; 10 months 20 days, at $75	900.00
1 clerk, 11 months, at $75	825.00
1 clerk, 1 month, at $75; 3 months, at $70	285.00
1 clerk, 1 month 22 days, at $75	133.93
1 clerk, 1 month, at $60; 2 months 49½ days, at $50	241.12
1 copyist, 1 month, at $70; 11 months, at $60	730.00
1 copyist, 3 months, at $40	120.00
1 messenger, 11 months, at $50	550.00
1 messenger, 1 month, at $50; 11 months, at $45	545.00
1 laborer, 2 months 15 days, at $40	100.00
1 skilled laborer, 1 month, at $40; 11 months, at $35	425.00
1 modeler, 2 months, at $60	120.00
Total salaries or compensation	30,817.80

Miscellaneous:

Drawings	$449.40	
Freight	357.13	
Miscellaneous	372.27	
Office furniture	328.37	
Office rental	999.96	
Publications	604.85	
Specimens	504.37	
Stationery	311.08	
Supplies	979.99	
Travel and field expenses	3,848.41	
		$8,755.83
		39,573.63
Balance July 1, 1895		5,680.15

NATIONAL MUSEUM.

PRESERVATION OF COLLECTIONS, JULY 1, 1894, TO JUNE 30, 1895.

Receipts.

Appropriation by Congress for the fiscal year ending June 30, 1895, "For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees" (sundry civil act, August 18, 1894)	$143,000.00

Expenditures.

Salaries or compensation:

DIRECTION.

1 Assistant Secretary of the Smithsonian Institution, in charge, 12 months, at $333.33	$3,999.96

SCIENTIFIC STAFF.

1 executive curator, 10 months, at $225, $2,250; 15 days, at $225, $108.87	2,358.87
1 curator, 12 months, at $200	2,400.00
1 curator, 12 months, at $200	2,400.00
1 curator, 12 months, at $200	2,400.00
1 curator, 12 months, at $175	2,100.00
1 curator, 5 months, at $175	875.00
1 curator, 11 months, at $140	1,540.00
1 curator, 8 months, at $100	800.00
1 assistant curator, 12 months, at $166.66	1,999.92
1 assistant curator, 12 months, at $150	1,800.00
1 assistant curator, 12 months, at $133.33	1,599.96
1 assistant curator, 12 months, at $125	1,500.00
1 assistant curator, 9 months, at $125	1,125.00
1 assistant curator, 5 days, at $120	19.35
1 assistant curator, 12 months, at $100	1,200.00
1 assistant curator, 4 months, at $70, $280; 8 months, at $80, $640	920.00
1 osteologist, 12 months, at $90	1,080.00
1 collector, 1 month, at $60; 16 days, at $60, $30.97	90.97
1 assistant, 12 months, at $75	900.00
1 aid, 12 months, at $100	1,200.00
1 aid, 12 months, at $80	960.00

Salaries or compensation—Continued.

1 aid, 12 months, at $50	$600.00
1 aid, 3 months, at $40	120.00
1 aid, 8 months, at $40, $320; 3 months, at $30, $90; 9 days, at $30, $8.71	418.71
PREPARATORS.	
1 photographer, 12 months, at $158.33	1,899.96
1 artist, 12 months, at $110	1,320.00
1 preparator, 7 months, at $90, $630; 24 days, at $90, $72	702.00
1 preparator, 12 months, at $80	960.00
1 preparator, 12 months, at $80	960 00
1 preparator, 12 months, at $80	960.00
1 preparator, 11 months, at $60, $660; 1 month, at $62, $62	722.00
1 preparator, 4 months, at $60	240.00
1 preparator, 7 months, at $50, $350; 5 days, at $50, 8.33	358.33
1 taxidermist, 9 months, at $100, $900; 15 days, at $100, $48.39; 24 days, at $100, $77.42	1,025.81
1 taxidermist, 12 months, at $100	1,200.00
1 taxidermist, 12 months, at $90	1,080.00
1 taxidermist, 9 months, at $75, $675; 12½ days, at $75, $30.24; 23½ days, at $75, $58.75; 21 days, at $75, $50.81	814.80
1 taxidermist, 12 months, at $60	720.00
CLERICAL STAFF.	
1 chief clerk, 4 months, at $187.50, $750; 8 months, at $200, $1,600	2,350.00
1 editor, 12 months, at $187.50	2,250.00
1 chief of division, 5 months, at $180, $900; 7 months, at $200, $1,400	2,300.00
1 registrar, 12 months, at $158.33	1,899.96
1 disbursing clerk, 7 months, at $100, $700; 5 months, at $116.66, $583.30	1,283.30
1 assistant librarian, 4 months, at $100, $400; 8 months, at $110, $880	1,280.00
1 stenographer, 7 months, at $85, $595; 5 months, at $110, $550	1,145.00
1 stenographer, 1 month, at $60, $60; 21 days, at $60, $42	102.00
1 stenographer, 12½ days, at $60	24.19
1 stenographer, 12 months, at $50	600.00
1 stenographer, 2 days, at $50	3.33
1 stenographer, 6 months, at $45, $270; 11 days, at $45, $15.97	285.97
1 typewriter, 12 months, at $50	600.00
1 typewriter, 207 days, at $1.50, $310.50; 11 days, at $1.25, $13.75	324.25
1 clerk, 3 months, at $125, $375, 8 months, at $80, $640; 25 days, at $80, $66.67	1,081.67
1 clerk, 12 months, at $115	1,380.00
1 clerk, 12 months, at $115	1,380.00
1 clerk, 12 months, at $100	1,200.00
1 clerk, 12 months, at $100	1,200.00
1 clerk, 4 months, at $90, $360; 8 months, at $100, $800	1,160.00
1 clerk, 3 months, at $100, $300; 22 days, at $100, $73.33; 15 days, at $100, $50; 15 days, at $100, $50	473.33
1 clerk, 7 months, at $90, $630; 1 month, at $100	730.00
1 clerk, 12 months, at $90	1,080.00
1 clerk, 9 months, at $75, $675; 3 months, at $90, $270	945.00
1 clerk, 12 months, at $83.33	999.96
1 clerk, 1 month, at $80	80.00

Salaries or compensation—Continued.

1 clerk, 1 month, at $75; 10 days, at $75, $24.19	$99.19
1 clerk, 12 months, at $70	840.00
1 clerk, 12 months, at $60	720.00
1 clerk, 12 months, at $60	720.00
1 clerk, 5 months, at $60	300.00
1 clerk, 4 months, at $60	240.00
1 clerk, 19 days, at $60, $38; 8 days, at $60, $15.48	53.48
1 clerk, 4 months, at $50, $200; 8 months, at $60, $480	680.00
1 clerk, 12 months, at $55	660.00
1 clerk, 12 months, at $55	660.00
1 clerk, 12 months, at $55	660.00
1 clerk, 12 months, at $50	600.00
1 clerk, 12 months, at $50	600.00
1 clerk, 8 months, at $50	400.00
1 clerk, 12 months, at $55	660.00
1 clerk, 12 months, at $50	600.00
1 clerk, 8 months, at $50, $400; 16 days, at $50, $25.81; 14 days, at $50, $22.58	448.39
1 copyist, 12 months, at $45	540.00
1 copyist, 12 months, at $40	480.00
1 copyist, 12 months, at $40	480.00
1 copyist, 12 months, at $40	480.00
1 copyist, 12 months, at $40	480.00
1 copyist, 12 months, at $40	480.00
1 copyist, 7 months, at $40	280.00
1 copyist, 4 months, at $30, $120; 1 month, at $40, $40; 15 days, at $40, $19.35	179.35
1 copyist, 12 months, at $35	420.00
1 copyist, 12 months, at $35	420.00
1 copyist, 12 months, at $35	420.00
1 copyist, 4 months, at $20, $80; 8 months, at $35, $280	360.00
1 copyist, 12 months, at $30	360.00
1 copyist, 12 months, at $30	360.00

BUILDINGS AND LABOR.

1 superintendent of building, 12 momths, at $137.50	1,650.00
1 assistant superintendent of building, 12 months, at $100	1,200.00
1 foreman, 12 months, at $50	600.00
1 chief of watch, 12 months, at $65	780.00
1 chief of watch, 12 months, at $65	780.00
1 watchman, 12 months, at $65	780.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 12 months, at $50	600.00
1 watchman, 11 months, at $50, $550; 28 days, at $50, $46.67	596.67
1 watchman, 3 months, at $50, $150; 21 days, at $50, $33.87; 23 days, at $50, $38.33; 12 days, at $50, $19.35	241.55
1 watchman, 3 months, at $50	150.00
1 watchman, 2 months, at $50	100.00

Salaries or compensation—Continued.

1 watchman, 1 month, at $50, $50; 15 days, at $50, $24.19	$74.19
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $45	540.00
1 watchman, 12 months, at $45	540.00
1 watchman, 10 months at $45, $450; 23 days, at $45, $34.84	484.84
1 watchman, 12 months, at $40	480.00
1 watchman, 11 months, at $40, $440; 17 days, at $40, $21.94	461.94
1 watchman, 4 months, at $40, $160; 15 days, at $40, $19.35; 29 days, at $40, $38.67	218.02
1 watchman, 1 month, at $40	40.00
1 watchman, 29 days, at $40	37.42
1 watchman, 6 months, at $35	210.00
1 skilled laborer, 12 months, at $52	624.00
1 skilled laborer, 5 months, at $50, $250; 10½ days, at $50, $16.94; 17 days, at $50, $28.33	295.27
1 skilled laborer, 12 months, at $45	540.00
1 skilled laborer, 50 days, at $3	150.00
1 skilled laborer, 165½ days, at $2	331.00
1 skilled laborer, 155 days, at $1.75	271.25
1 laborer, 12 months, at $60	720.00
1 laborer, 9 months, at $45, $405; 1 month, at $49.50, $49.50; 1 month, at $46.50, $46.50; 1 month, at $48, $48	549.00
1 laborer, 9 months, at $40, $360; 1 month, at $44.50, $44.50; 2 months, at $46, $92	496.50
1 laborer, 4 months, at $40, $160; 1 month, at $41.50, $41.50; 23 days, at $40, $30.67; 21 days, at $40, $27.10; 29½ days, at $40, $39.33	298.60
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 12 months, at $40	480.00
1 laborer, 11 months, at $40, $440; 25 days, at $40, $32.26	472.26
1 laborer, 11 months, at $40, $440; 16 days, at $40, $22.86	462.86
1 laborer, 3 months, at $40	120.00
1 laborer, 333 days, at $1.50	499.50
1 laborer, 331 days, at $1.50	496.50
1 laborer, 317 days, at $1.50	475.50
1 laborer, 313 days, at $1.50	469.50
1 laborer, 313 days, at $1.50	469.50
1 laborer, 312 days, at $1.50	468.00
1 laborer, 312 days, at $1.50	468.00
1 laborer, 312 days, at $1.50	468.00
1 laborer, 312 days, at $1.50	468.00
1 laborer, 285¾ days, at $1.50	428.63
1 laborer, 283 days, at $1.50	424.50
1 laborer, 261½ days, at $1.50	392.25
1 laborer, 260½ days, at $1.50	390.75
1 laborer, 241¾ days, at $1.50	362.63
1 laborer, 241 days, at $1.50	361.50
1 laborer, 224 days, at $1.50	336.00
1 laborer, 175 days, at $1.50	262.50
1 laborer, 115 days, at $1.50	172.50
1 laborer, 83 days, at $1.50	124.50

Salaries or compensation—Continued.

1 laborer, 36 days, at $1.50		$54.00
1 laborer, 10¾ days, at $1.50		16.13
1 laborer, 10¾ days, at $1.50		16.13
1 laborer, 10¾ days, at $1.50		16.13
1 laborer, 10¾ days, at $1.50		16.13
1 laborer, 10 days, at $1.50		15.00
1 laborer, 10 days, at $1.50		15.00
1 laborer, 9 days, at $1.50		13.50
1 laborer, 8¾ days, at $1.50		13.13
1 laborer, 6 days, at $1.50		9.00
1 laborer, 3 days, at $1.50		4.50
1 laborer, 48 hours, at 18¾ cents		9.00
1 laborer, 48 hours, at 18¾ cents		9.00
1 messenger, 8 months, at $50		400.00
1 messenger, 1 month, at $45, $45; 4 days, at $45, $5.81		50.81
1 messenger, 12 months, at $30		360.00
1 messenger, 12 months, at $30		360.00
1 messenger, 4 months, at $20, $80; 8 months, at $25, $200		280.00
1 messenger, 4 months, at $25		100.00
1 messenger, 12 months, at $20		240.00
1 messenger, 8 months, at $20, $160; 16 days, at $20, $10.32		170.32
1 messenger, 15 days, at $20, $10; 18 days, at $20, $11.61		21.61
1 messenger, 8 months, at $15, $120; 17 days, at $15, $8.23		128.23
1 messenger, 7 months, at $15, $105; 12 days, at $15, $6		111.00
1 messenger, 4 months, at $15		60.00
1 attendant, 12 months, at $40		480.00
1 cleaner, 11 months, at $30, $330; 29 days, at $30, $29		359.00
1 cleaner, 12 months, at $30		360.00
1 cleaner, 12 months, at $30		360.00
1 cleaner, 12 months, at $30		360.00
1 cleaner, 312 days, at $1		312.00
1 cleaner, 310 days, at $1		310.00
Total salaries		126,142.26
Special services		3,381.24
Total services		129,523.50
Miscellaneous:		
Supplies	$2,276.56	
Stationery	811.62	
Specimens	2,367.14	
Books and periodicals	$1,014.68	
Travel	585.64	
Freight and cartage	1,469.98	8,525.62
Total expenditure		138,049.12
Balance July 1, 1895		4,950.88

National Museum: Furniture and fixtures, July 1, 1894, to June 30, 1895.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1895, "For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees" (sundry civil act, August 18, 1894)	$10,000.00

EXPENDITURES.

Salaries or compensation:		
1 cabinetmaker, 360 days, at $3		$918.00
1 carpenter, 312 days, at $3		936.00
1 carpenter, 190 days, at $3		570 00
1 carpenter, 91 days, at $3		273 00
1 carpenter, 114 days, at $3		342 00
1 carpenter, 86½ days, at $3		259.50
1 carpenter, 42 days, at $3		126.00
1 carpenter, 41 days, at $3		123.00
1 carpenter, 76 days, at $3		228.00
1 carpenter, 32 days, at $3		96.00
1 carpenter, 18 days, at $3		54.00
1 carpenter, 22½ days, at $3		67.50
1 carpenter, 13 days, at $3		39.00
1 painter, 12 months, at $65		780.00
1 skilled laborer, 157 days, at $1.75		274.75
1 skilled laborer, 3 months at $50, $150; 19½ days, at $50, $31.45		181.45
1 skilled laborer, 75½ days, at $2		151.00
1 laborer, 3 months, at $40, $120; 1 month, at $41.50, $41.50		161.50
1 laborer, 19 days, at $1.50		28.50
		5,609.20
Special services		86.13
		5,695.33
Miscellaneous:		
Drawings	$91.25	
Drawers, trays, boxes	671.79	
Frames, stands, etc	67.00	
Glass	45.90	
Hardware	510.30	
Tools	63.69	
Cloth, cotton, etc	20.00	
Glass jars	248.32	
Lumber	1,108.22	
Paints, oils, etc	450.14	
Office furniture	122.73	
Metals	47.16	
Rubber and leather	18.80	
Iron brackets	141.94	
		3,607.24
Total expenditure		9,302.57
Balance July 1, 1895, to meet outstanding liabilities		697.43

National Museum: Heating, lighting, electric and telephonic service, July 1, 1894, to June 30, 1895.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1895, "For expense of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum" (sundry civil act, August 18, 1894)	$13,000.00

EXPENDITURES.

Salaries or compensation:	
1 engineer, 12 months, at $115	1,380.00
1 fireman, 12 months, at $50	600.00
1 fireman, 11 months, at $50, $550; 29½ days, at $50, $47.58	597.58

Salaries or compensation—Continued.		
1 fireman, 10 months, at $50, $500; 30½ days, at $50, $49.19; 6 days, at $50, $10		$559.19
1 fireman, 8 months, at $75, $600; 3 months, at $60, $180; 25 days, at $60, $48.39		828.39
1 fireman, 1 month, at $50, $50; 26 days, at $50, $41.94; 13 days, at $50, $20.96		112.90
1 fireman, 2 months, at $54, $108; 2 months, at $50, $100		208.00
1 fireman, 19 days, at $50		33.93
1 steam fitter, 1 month, at $50, $50; 16 days, at $50, $25.81		75.81
1 laborer, 6 months, at $40, $240; 2 months, at $46, $92; 1 month, at $41.50, $41.50		373.50
1 laborer, 244 days, at $1.25		305.00
1 laborer, 177½ days, at $1.25		221.88
1 laborer, 98½ days, at $1.50		147.75
1 laborer, 89 days, at $1.50		133.50
1 clerk, 4 months, at $35, $140; 1 month, at $40, $40		180.00
1 telephone clerk, 7 months, at $60		420.00
		6,177.43
Special services		51.25
Total services		6,228.68
General expenses:		
Coal and wood	$2,791.90	
Gas	1,455.88	
Telephones	444.00	
Electric supplies	210.75	
Rental of call boxes	90.00	
Heating supplies	327.41	
Telegrams	6.31	
		5,326.25
Total expenditure		11,554.93
Balance July 1, 1895		1,445.07

National Museum: Postage, July 1, 1894, to June 30, 1895.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1895, "For postage stamps and foreign postal cards for the National Museum" (sundry civil act, August 18, 1894)	$500.00

EXPENDITURES.

City post-office for stamps, etc. (appropriation expended)	500.00

National Museum: Printing, July 1, 1894, to June 30, 1895.

RECEIPTS.

Appropriation by Congress for the fiscal year ending June 30, 1895, "For the Smithsonian Institution for printing labels and blanks and for the 'Bulletins' and annual volumes of the 'Proceedings' of the National Museum"	$11,000.00
For binding scientific books and pamphlets presented to and acquired by the National Museum library (sundry civil act, August 18, 1894)	1,000.00
	12,000.00

EXPENDITURES.

Bulletins National Museum, Nos. 39, 47, 48, and special Nos. 2 and 3	$6,202.53	
Proceedings National Museum, Vol. XVII	3,179.93	
Reports National Museum, extras	28.06	
Labels for specimens	234.78	
Letter heads, pads, and envelopes	610.18	
Blanks	413.60	
Electros	14.50	
Binding	1,258.60	
Congressional Records	20.00	
Total expenditure		$11,962.18
Balance July 1, 1895		37.82

National Museum: Rent of workshops.

Balance July 1, 1894, as per last annual report		$457.29
Appropriation by Congress, "under Smithsonian Institution," "For rent for workshops for the National Museum" (sundry civil act, August 18, 1894)		600.00
		1,057.29

EXPENDITURES.

Lumber	$29.75	
Rent	975.00	
		1,004.75
Balance July 1, 1895		52.54

Building, National Museum: Repairs, 1895.

RECEIPTS.

Appropriation by Congress for tearing down and rebuilding the brick walls of the steam boilers, providing tie-rods and buck-staves and grates for the same; removing, replacing, and resetting the fronts, and replacing worn-out boiler tubes and for covering heating pipes with fireproof material, including all necessary labor and material (sundry civil act, August 18, 1894)	$4,000.00

EXPENDITURES FROM JULY 1, 1894, TO JUNE 30, 1895.

Services:			
1 bricklayer, 1 day, at $5	$5.00		
1 bricklayer, 11½ days, at $4	46.00		
3 skilled laborers, 27 days, at $3	81.00		
1 skilled laborer, 24 days, at $50 per month	40.00		
19 laborers, 298¾ days, at $1.50	448.13		
2 painters, 14 days, at $3	42.00		
		$662.13	
Brickwork (by contract)		1,378.00	
Boiler tubes		594.00	
Boiler compound		56.00	
Polishing compound		8.75	
Iron water-headers		200.00	
Iron grate-bars		109.78	
Magnesia pipe covering		916.20	
Pipe fittings		18.88	
Asphaltum and bronze		2.50	
Plastering		7.80	
Advertising proposals		32.67	
			3,986.71
Balance July 1, 1895			13.29

Preservation of collections, 1894.

Balance July 1, 1894, as per last annual report			$4,180.20

EXPENDITURES.

Salaries or compensation	$165.00		
Special or contract services	489.21		
		$654.21	
Supplies		960.58	
Stationery		132.78	
Specimens		756.19	
Books and periodicals		620.96	
Travel		122.42	
Freight and cartage		697.79	
Total expenditure			3,944.93
Balance July 1, 1895			235.27

Total expenditure of the appropriation for preservation of collections, 1894.

Appropriation			$132,500.00

EXPENDITURES.

Salaries or compensation	$118,406.94		
Special or contract work	2,242.32		
		$120,649.26	
Supplies		2,356.36	
Stationery		496.05	
Specimens		3,810.74	
Travel		572.30	
Freight		3,117.34	
Books		1,262.68	
Total expenditure			132,264.73
Balance July 1, 1895			235.27

Preservation of collections, 1893.

Balance July 1, 1894, as per last annual report		$318.02

EXPENDITURES.

Services (special)	$0.75	
Specimens	276.00	
Supplies	39.00	
Total expenditure		315.75
Balance July 1, 1895		2.27

Total expenditure of appropriation for preservation of collections, 1893.

Appropriations		$132,500.00	
		2,000.00	
			$134,500.00

EXPENDITURES.

Salaries or compensation	$116,234.65		
Special or contract services	2,794.53		
		$119,029.18	

Supplies	$3,239.96	
Stationery	1,717.29	
Specimens	6,415.56	
Books	1,032.54	
Travel	707.47	
Freight	2,355.73	
Total expenditure		$134,497.73
Balance July 1, 1895		2.27

Furniture and fixtures, 1894.

Balance July 1, 1894, as per last annual report		$803.24

EXPENDITURES.

Frames, stands, etc	$62.70	
Glass	40.00	
Hardware	35.15	
Tools	5.00	
Colth, etc	48.75	
Lumber	72.35	
Paints, oils, etc	111.26	
Office furniture	330.66	
Metals	6.05	
Rubber and leather	4.98	
Apparatus	2.25	
Cases	84.00	
Total expenditure July 1, 1894, to June 30, 1895		803.15
Balance July 1, 1895		.09

Total expenditure of the appropriation for furniture and fixtures, 1894.

Appropriation			$10,000.00

EXPENDITURES.

Salaries or compensation	$5,525.75		
Special or contract services	29.25		
		$5,555.00	
Cases		84.00	
Drawings		9.25	
Drawers		321.50	
Frames		121.68	
Glass		143.82	
Hardware		530.34	
Tools		37.13	
Cloth		103.02	
Glass jars		501.81	
Lumber		899.26	
Paints, oil, etc		666.09	
Office furniture		540.61	
Metals		70.73	
Rubber and leather		22.26	
Apparatus		48.49	
Slate, brick, etc		201.50	
Iron brackets		143.42	
Total expenditure			9,999.91
Balance July 1, 1895			.09

National Museum: Furniture and fixtures, 1893.

Balance July 1, 1894, as per last annual report	$0.16

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1895.

Heating and lighting, 1894.

Balance July 1, 1894, as per last annual report		$724.30
EXPENDITURES.		
Special or contract services	$6.25	
Coal and wood	24.75	
Gas	78.50	
Telephones	165.50	
Electrical supplies	50.60	
Rental call boxes	20.00	
Heating supplies	348.48	
Telegrams	29.46	
Total expenditure		723.54
Balance July 1, 1895		.76

Total expenditure of the appropriation for heating, lighting, etc., 1894.

Appropriation			$11,000.00
EXPENDITURES.			
Salaries or compensation	$5,034.75		
Special or contract services	67.75		
		$5,102.50	
Coal and wood		2,696.55	
Gas		1,446.26	
Telephones		687.62	
Electric supplies		163.16	
Rental call boxes		120.00	
Heating repairs		12.00	
Heating supplies		741.69	
Telegrams		29.46	
Total expenditure			10,999.24
Balance July 1, 1895			.76

Heating, lighting, etc., 1893.

Balance July 1, 1894, as per last annual report	$11.10

Balance carried, under the provisions of the Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1895.

SMITHSONIAN INSTITUTION BUILDING—REPAIRS.

RECEIPTS.

Balance July 1, 1894, as per last annual report	$1.14

Balance carried, under the provisions of the Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1895.

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1895.

RECEIPTS.

Appropriation by Congress "For maintenance of the Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, apparatus, and miscellaneous expenses" (sundry civil act, August 18, 1894)	$9,000.00

EXPENDITURES FROM JULY 1, 1894, TO JUNE 30, 1895.

Salaries or compensation:			
1 aid, 12 months, at $125		$1,500.00	
1 assistant, 12 days, at $100		40.00	
1 junior assistant, 11 months, at $66.66; 1 month at $83.33		816.59	
1 clerk, 1 month, at $100		100.00	
1 clerk, 12 months, at $60		720.00	
1 instrument maker, 99⅜ days, at $3.50		344.41	
1 assistant instrument maker, 9½ months, at $60; 25 days, at $60; 2½ days, at $65		624.43	
3 carpenters, 41¼ days, at $3		123.75	
1 painter, 1 day, at $50		1.66	
2 steam fitters, 10½ days, at $3		31.50	
1 skilled laborer, 2 days, at $2.50		5.01	
6 laborers, 58½ days, at $1.50		87.75	
1 cleaner, 22 days, at $1		22.00	
Total salaries or compensation		4,417.00	
General expenses:			
Apparatus	$1,726.71		
Books and binding	135.46		
Building	172.00		
Castings	12.15		
Freight	17.77		
Illustrations	23.70		
Lumber	133.56		
Postage and telegraph	2.23		
Stationery	6.72		
Supplies	690.52		
Traveling expenses	77.17		
		2,997.99	
			7,414.99
Balance July 1, 1895			1,585.01

ASTROPHYSICAL OBSERVATORY, SMITHSONIAN INSTITUTION, 1894.

Balance July 1, 1894, as per last annual report	$75.90

EXPENDITURES JULY 1, 1894, TO JUNE 30, 1895.

General expenses:		
Apparatus	$10.98	
Castings	1.20	
Freight	27.35	
Stationery	2.99	
Supplies	24.36	
		66.88
Balance July 1, 1895		9.02

ASTROPHYSICAL OBSERVATORY, 1893.

Balance July 1, 1894, as per last annual report	$0.01

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1895.

NATIONAL ZOOLOGICAL PARK, 1895.

Appropriation by Congress "For continuing the construction of roads, walks, bridges, water supply, sewerage and drainage, and for grading, planting, and otherwise improving the grounds, erecting and repairing buildings and inclosures for animals, and for administrative purposes, care, subsistence, and transportation of animals, including salaries or compensation of all necessary employees and general incidental expenses not otherwise provided for, $50,000, one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States. A report in detail of the expenses on account of the National Zoological Park shall be made to Congress at the beginning of each regular session" (sundry civil act, August 18, 1894)	$50,000.00

EXPENDITURES JULY 1, 1894, TO JUNE 30, 1895.

Salaries or compensation:		
1 superintendent, 12 months, at $208.33	$2,499.96	
1 property clerk, 12 months, at $125	1,500.00	
1 foreman, 5 months 4 days, at $75	384.68	
1 foreman, 5½ months, at $75	412.50	
1 assistant foreman, 12 months, at $60	720.00	
1 head keeper, 12 months, at $83.33	999.96	
5 under keepers, 12 months, at $50	3,000.00	
1 blacksmith, 12 months, at $75	900.00	
1 assistant blacksmith, 12 months, at $60	720.00	
1 carpenter, 2½ months, at $65	162.50	
1 carpenter, 12 months, at $65	780.00	
1 watchman, 6 months, at $50; 1 laborer, 6 months, at $50	600.00	
1 watchman, 12 months, at $50	600.00	
1 watchman, 11½ months, at $60; ½ month, at $50	715.00	
1 night watchman, 5 months, at $45; 7 months, at $50	575.00	
1 laborer, 12 months, at $45	540.00	
1 laborer, 3 months, at $45; 9 months, at $50	585.00	
2 laborers, 4 months, at $45; 8 months, at $50	1,160.00	
1 laborer, 12 months, at $50	600.00	
1 laborer, 9½ months, at $45	427.50	
1 laborer, 6 months, at $25; 6 months, at $35	360.00	
1 messenger, 12 months, at $35	420.00	
1 attendant, 12 months, at $15	180.00	
1 stenographer, 12 months, at $62.50	750.00	
1 clerk, 7 months 8 days, at $60	437.14	
1 clerk, 4 months, at $60	240.00	
		20,269.24
Miscellaneous:		
Bridges and culverts	607.97	
Building material, lime, stone, etc	1,066.27	
Fencing and cage material	881.61	
Food	4,438.82	
Freight and transportation	972.13	
Fuel	592.81	
Granolithic pavement	50.25	
Lumber	939.87	

Miscellaneous—Continued.		
Machinery, tools, etc	$330.75	
Miscellaneous supplies	682.94	
Paints, oils, glass, etc	180.44	
Postage, telegraph, and telephones	155.51	
Riprap material	269.37	
Road material and grading	5,298.95	
Stationery, books, printing, etc	154.62	
Surveying, plans, etc	426.67	
Traveling expenses	239.30	
Trees, plants, sodding, etc	835.04	
Water supply and sewerage	478.30	
		$18,601.62
Wages of mechanics and laborers and hire of teams in constructing buildings and inclosures, laying water pipes, building roads, gutters, and walks, planting trees, and otherwise improving the grounds:		
1 laborer, 156 days, at $1.50	234.00	
1 laborer, 106¼ days, at $1.50	159.38	
1 laborer, 134 days, at $1.50	201.00	
1 laborer, 220¾ days, at $1.50	331.14	
1 laborer, 390½ days, at $1.50	585.75	
1 laborer, 151¼ days, at $1.50	226.87	
1 laborer, 149½ days, at $1.50	224.25	
1 laborer, 181 days, at $1.50	271.50	
1 laborer, 258 days, at $1.50	387.01	
1 laborer, 162 days, at $1.50	243.00	
1 laborer, 273 days, at $1.50	409.50	
1 laborer, 90¾ days, at $1.50	136.13	
1 laborer, 2 days, at $1.50	3.00	
1 laborer, 311¾ days, at $1.50	467.62	
1 laborer, 226½ days, at $1.50	339.75	
1 laborer, 82 days, at $1.50	123.00	
1 laborer, 113½ days, at $1.50	170.25	
1 laborer, 2 days, at $1.50	3.00	
1 laborer, 43 days, at $1.25; 61 days, at $1.50	145.25	
1 laborer, 111½ days, at $1.25	139.37	
1 laborer, 142½ days, at $1.25	178.13	
1 laborer, 116¾ days, at $1.25	145.94	
1 laborer, 117¼ days, at $1.25	146.55	
1 laborer, 167 days, at $1.25	208.75	
1 laborer, 32¾ days, at $1.25	40.94	
1 laborer, 25 days, at $1.25	31.25	
1 laborer, 35¼ days, at $1.25; 85¾ days, at $1.50	172.68	
1 laborer, 147 days, at $1.25	183.75	
1 laborer, 115¼ days, at $1.25	144.06	
1 laborer, 120¼ days, at $1.25	150.31	
1 laborer 269⅝ days, at $1.25	337.02	
1 laborer, 156¾ days, at $1.25	195.93	
1 laborer, 19 days, at $1.25; 76¾ days, at $1.50	138.87	
1 laborer, 101¼ days, at $1.25.	126.56	
1 laborer, 105 days, at $1.25	131.25	
1 laborer, 33¾ days, at $1.25	42.19	
1 laborer, 82¾ days, at $1.25	103.43	
1 laborer, 5 days, at $1.25	6.25	
1 laborer, 51¼ days, at $1.25	64.06	
1 laborer, 49¾ days, at $1.25	62.18	

Wages of mechanics and laborers, etc.—Continued.		
1 paver, 38 days, at $2; laborer, 45½ days, at $1.50	$144.25	
1 laborer, 53 days, at $1; 128 days, at 75 cents	149.00	
1 tool boy, 107 days, at $1; laborer, 228 days, at $1.25	392.00	
1 laborer, 3 days, at 50 cents	1.50	
1 carpenter, 151½ days, at $2.80; laborer, 14 days, at $1.50	445.20	
1 water boy, 165¾ days, at 50 cents	82.87	
1 stone mason, 6 days, at $2.50	15.00	
1 stone mason, 2 days, at $2.50; laborer, 27¼ days, at $1.75; 42¼ days, at $2; 4½ months, at $45	339.69	
1 stone mason, 35 days, at $2.50	87.50	
1 wagon and team, 41¼ days, at $3.50; mower and team, 5½ days, at $3.50	163.63	
1 wagon and team, 45½ days, at $3.50	159.25	
1 wagon and team, 9¼ days, at $3.50	32.37	
1 wagon and team, 1 day, at $3.50	3.50	
1 cart and horse, 44 days, at $1.75	77.00	
1 cart and horse, 4 days, at $1.75	7.00	
1 cart and horse, 4 days, at $1.75	7.00	
1 cart and horse, 4 days, at $1.75	7.00	
1 cart and horse, 57 days, at $1.75	99.75	
1 cart and horse, 19 days, at $1.75	33.25	
1 cart and horse, 24 days, at $1.75	42.00	
1 cart and horse, 32 days, at $1.75	56.00	
1 horse, 61 days, at 50 cents	30.50	
1 horse, 3 days, at 50 cents	1.50	
1 painter, 9 days, at $2.80	25.20	
1 stone breaker, 147⅔ cubic yards, at 60 cents	88.60	
1 stone breaker, 134½ cubic yards, at 60 cents	80.70	
1 stone breaker, $105\frac{1}{12}$ cubic yards, at 60 cents	63.05	
		10,045.18
Total expenditure		48,916.04
Balance July 1, 1895		1,083.96

ENTRANCE AND DRIVEWAY, ZOOLOGICAL PARK, DISTRICT OF COLUMBIA, 1895 AND 1896.

Appropriation by Congress "For continuing the entrance into the Zoological Park from Woodley Lane and opening driveway into Zoological Park from said entrance along the west bank of Rock Creek, $5,000, to be immediately available, which sum is hereby appropriated out of any money in the Treasury not otherwise appropriated, one-half chargeable to the revenues of the District of Columbia"			$5,000.00
Salaries or compensation:			
9 laborers, 144⅗ days, at $1.50	$216.88		
4 laborers, 90 days, at $1.25	112.49		
1 water boy, 43¼ days, at 50 cents	21.63		
1 wagon and team, 20 days, at $3.50	70.00		
1 wagon and team, 5 days, at $3.50	17.50		
		$438.50	
General expenses:			
Drawing instruments, etc	83.98		
Grading	2,086.65		
Machinery, tools, etc	166.20		
		2,336.83	
Total disbursements			2,775.33
Balance July 1, 1895			2,224.67

NATIONAL ZOOLOGICAL PARK, 1894.

Balance July 1, 1894, as per last annual report		$1,537.41

EXPENDITURES FROM JULY 1, 1894, TO JUNE 30, 1895.

Building material	$2.00	
Freight and transportation	100.57	
Food for animals	371.74	
Iron, steel, fencing, hardware, etc	42.46	
Miscellaneous supplies	171.90	
Paints, oil, etc	10.70	
Stationery, printing, etc	12.50	
Services	89.88	
Surveying, plans, etc	495.00	
Total expenditure		1,296.75
Balance July 1, 1895		240.66

NATIONAL ZOOLOGICAL PARK, 1893.

Balance July 1, 1894, as per last annual report	$0.02

Balance carried, under the provisions of Revised Statutes, section 3090, by the Treasury Department to the credit of the surplus fund June 30, 1895.

RECAPITULATION.

The total amount of funds administered by the Institution during the year ending June 30, 1895, appears from the foregoing statements and the account books to have been as follows:

Smithsonian Institution.

From balance of last year, July 1, 1894		$59,598.50	
(Including cash from executors of Dr. J. H. Kidder)	$5,000.00		
(Including cash from gift of Alex. Graham Bell)	5,000.00		
	10,000.00		
From interest on Smithsonian fund for the year		54,473.92	
From sales of publications		254.59	
From repayments of freight, etc		5,819.79	
Interest on West Shore bonds		1,680.00	
			$121,826.80

Appropriations committed by Congress to the care of the Institution.

International Exchanges—Smithsonian Institution:		
From balance of 1892–93	$0.44	
From balance of 1893–94	25.42	
From appropriation for 1894–95	17,000.00	
		17,025.86
North American Ethnology:		
From balance of last year, July 1, 1894	5,253.78	
From appropriation for 1894–95	40,000.00	
		45,253.78
Preservation of collections—Museum:		
From balance of 1892–93	318.02	
From balance of 1893–94	4,180.20	
From appropriation for 1894–95	143,000.00	
		147,498.22
Printing—Museum:		
From balance of 1893–94	43.82	
From appropriation for 1894–95	12,000.00	
		12,043.82

Furniture and fixtures—Museum:		
From balance of 1892–93	$0.16	
From balance of 1893–94	803.24	
From appropriation for 1894–95	10,000.00	
		$10,803.40
Heating and lighting, etc.—Museum:		
From balance of 1892–93	11.10	
From balance of 1893–94	724.30	
From appropriation for 1894–95	13,000.00	
		13,735.40
Smithsonian Institution building, repairs		1.14
Rent of workshops, etc.—Museum:		
From balance of 1893–94	457.29	
From appropriation for 1894–95	600.00	
		1,057.29
Postage—Museum:		
From appropriation for 1894–95		500.00
Building repairs—Museum:		
From appropriation for 1894–95		4,000.00
National Zoological Park:		
From balance of 1892–93	.02	
From balance of 1893–94	1,537.41	
From appropriation for 1894–95	50,000.00	
		51,537.43
Astrophysical Observatory, Smithsonian Institution:		
From balance of 1892–93	.01	
From balance of 1893–94	75.90	
From appropriation for 1894–95	9,000.00	
		9,075.91
Summary:		
Smithsonian Institution	121,826.80	
Exchanges	17,025.86	
Ethnology	45,253.78	
Preservation of collections	147,498.22	
Printing	12,043.82	
Furniture and fixtures	10,803.40	
Heating and lighting	13,735.40	
Rent of workshop	1,057.29	
Postage	500.00	
National Museum building, repairs	4,000.00	
Smithsonian Institution building, repairs	1.14	
National Zoological Park	51,537.43	
Astrophysical Observatory	9,075.91	
		434,359.05

The committee has examined the vouchers for payment from the Smithsonian income during the year ending June 30, 1895, each of which bears the approval of the Secretary or, in his absence, of the acting secretary, and a certificate that the materials and services charged were applied to the purposes of the Institution.

The committee has also examined the accounts of the several appropriations committed by Congress to the Institution, and finds that the balances hereinbefore given correspond with the certificates of the disbursing clerk of the Smithsonian Institution, whose appointment as

such disbursing officer has been accepted and his bond approved by the Secretary of the Treasury.

The quarterly accounts current, the vouchers, and journals have been examined and found correct.

Statement of regular income from the Smithsonian fund available for use in the year ending June 30, 1896.

Balance on hand June 30, 1895		$63,001.74
(Including cash from executors of J. H. Kidder)	$5,000.00	
(Including cash from Dr. Alex. Graham Bell)	5,000.00	
	10,000.00	
Interest due and receivable July 1, 1895	27,355.00	
Interest due and receivable January 1, 1896	27,360.00	
Interest, West Shore Railroad bonds, due July 1, 1895	840.00	
Interest, West Shore Railroad bonds, due January 1, 1896	840.00	
		56,395.00
Total available for year ending June 30, 1896		119,396.74

Respectfully submitted.

J. B. HENDERSON,
Executive Committee.

WASHINGTON, D. C., *January 8, 1896.*

ACTS AND RESOLUTIONS OF CONGRESS RELATIVE TO THE SMITHSONIAN INSTITUTION, NATIONAL MUSEUM, ETC.

(In continuation from previous reports.)

[Fifty-third Congress, third session, December 3, 1894, to March 2, 1895.]

SMITHSONIAN INSTITUTION.

Resolved by the Senate and House of Representatives of the United States of America in Congress assembled, That the vacancy in the Board of Regents of the Smithsonian Institution other than Members of Congress, caused by the death of James C. Welling, of the city of Washington, be filled by the appointment of Gardiner G. Hubbard, a citizen of Washington, of the District of Columbia. (Joint resolution No. 21, approved February 27, 1895, statutes of the Fifty-third Congress, p. 972.)

Annual Report.—Of the Report of the Smithsonian Institution, ten thousand copies—one thousand for the Senate, two thousand for the House, five thousand for distribution by the Smithsonian Institution, and two thousand for distribution by the National Museum. (Act providing for public printing and binding, approved January 12, 1895, statutes of the Fifty-third Congress, p. 616.)

INTERNATIONAL EXCHANGES.

For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, seventeen thousand dollars. (Sundry civil appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 924.)

United States Geological Survey.—For the purchase of necessary books for the library, and the payment for the transmission of public documents through the Smithsonian exchange, two thousand dollars. (Sundry civil appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 940.)

War Department.—For the transportation of reports and maps to foreign countries through the Smithsonian Institution, one hundred dollars. (Sundry civil appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 960.)

Naval Observatory.—For repairs to buildings, fixtures, and fences, furniture, gas, chemicals, and stationery; freight (including transmission

of public documents through the Smithsonian exchange), foreign postage, and expressage, plants, fertilizers, and all contingent expenses, two thousand five hundred dollars. (Legislative, executive, and judicial appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 792.)

Patent Office.—For purchase of professional and scientific books, and expenses of transporting publications of patents issued by the Patent Office to foreign Governments, two thousand dollars. (Legislative, executive, and judicial appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 797.)

NATIONAL MUSEUM.

For continuing the preservation, exhibition, and increase of the collections from the surveying and exploring expeditions of the Government, and from other sources, including salaries or compensation of all necessary employees, one hundred and forty-three thousand two hundred and twenty-five dollars.

For cases, furniture, fixtures, and appliances required for the exhibition and safe-keeping of the collections of the National Museum, including salaries or compensation of all necessary employees, twelve thousand five hundred dollars.

For expenses of heating, lighting, electrical, telegraphic, and telephonic service for the National Museum, thirteen thousand dollars.

For postage stamps and foreign postal cards for the National Museum, five hundred dollars.

For repairs to buildings, shops, and sheds, National Museum, including all necessary labor and material, four thousand dollars.

For rent of workshops for the National Museum, nine hundred dollars.

For expenses of putting in four additional fire plugs in the Smithsonian Grounds for the better protection of the Smithsonian Institution, National Museum, and Astrophysical Observatory, and the purchase of necessary fire hose, eight hundred dollars. (Sundry civil appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 924.)

For the Smithsonian Institution, for printing labels and blanks, and for the "Bulletins" and annual volumes of the "Proceedings" of the National Museum, and binding scientific books and pamphlets, presented to and acquired by the National Museum library, twelve thousand dollars. (Sundry civil appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 960.)

NORTH AMERICAN ETHNOLOGY.

For continuing ethnological researches among the American Indians, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, forty thousand dollars,

of which sum not exceeding one thousand dollars may be used for rent of building. (Sundry civil appropriation act, approved March 2, 1895, statutes of Fifty-third Congress, p. 925.)

ASTROPHYSICAL OBSERVATORY.

For maintenance of Astrophysical Observatory, under the direction of the Smithsonian Institution, including salaries of assistants, apparatus, and miscellaneous expenses, nine thousand dollars. (Sundry civil appropriation act, approved March 2, 1895, statutes of the Fifty-third Congress, p. 924.)

NATIONAL ZOOLOGICAL PARK.

For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures for animals; and for administrative purposes, care, subsistence, and transportation of animals, including salaries or compensation of all necessary employees, and general incidental expenses not otherwise provided for, fifty-five thousand dollars, one half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States; for continuing the entrance into the Zoological Park from Woodley Lane, and opening driveway into Zoological Park, from said entrance along the west bank of Rock Creek, five thousand dollars, to be immediately available, which sum is hereby appropriated out of any money in the Treasury not otherwise appropriated, one-half chargeable to the revenues of the District of Columbia. And of the sum hereby appropriated five thousand dollars shall be used toward the construction of a road from the Holt Mansion entrance (on Adams Mill road) into the park to connect with the roads now in existence, including a bridge across Rock Creek. (Sundry civil appropriation act, approved March 2, 1895, statutes of Fifty-third Congress, p. 924.)

AMERICAN HISTORICAL ASSOCIATION.

Of the Report of the American Historical Association, three thousand copies; five hundred for the Senate, one thousand for the House, and one thousand five hundred for distribution by the association and the Smithsonian Institution. (Act providing for Public Printing and Binding, approved January 12, 1895, statutes of the Fifty-third Congress, p. 616.)

REPORT

OF

S. P. LANGLEY,

SECRETARY OF THE SMITHSONIAN INSTITUTION,

FOR THE YEAR ENDING JUNE 30, 1895.

To the Board of Regents of the Smithsonian Institution.

GENTLEMEN: In accordance with established custom I have the honor to submit herewith a report of the operations of the Smithsonian Institution for the year ending June 30, 1895, including the work placed by Congress under its supervision in the National Museum, the Bureau of Ethnology, the Bureau of International Exchanges, the National Zoological Park, and the Astro-physical Observatory.

I have given briefly in the body of the report a general account of the affairs of the Institution and of its bureaus for the year, reserving for the appendix the more detailed and statistical reports from the officers in charge of the different branches of work.

The full report upon the National Museum by the assistant secretary, Dr. G. Brown Goode, occupies a separate volume (Report of the Smithsonian Institution, National Museum, 1895).

THE SMITHSONIAN INSTITUTION.

THE ESTABLISHMENT.

The changes in the heads of the Executive Departments of the Government have affected likewise the Smithsonian establishment, which, as organized at the end of the year, consisted of the following ex officio members:

GROVER CLEVELAND, *President of the United States.*
ADLAI E. STEVENSON, *Vice-President of the United States.*
MELVILLE W. FULLER, *Chief Justice of the Supreme Court of the United States.*
RICHARD OLNEY, *Secretary of State.*
JOHN G. CARLISLE, *Secretary of the Treasury.*
DANIEL S. LAMONT, *Secretary of War.*
JUDSON HARMON, *Attorney-General.*
WILLIAM L. WILSON, *Postmaster-General.*
HILARY A. HERBERT, *Secretary of the Navy.*
HOKE SMITH, *Secretary of the Interior.*
J. STERLING MORTON, *Secretary of Agriculture.*

THE BOARD OF REGENTS.

In accordance with a resolution of the Board of Regents adopted January 8, 1890, by which its annual meeting occurs on the fourth Wednesday of each year, the Board met on January 23, 1895, at 10 o'clock a. m. The journal of its proceedings will be found, as hitherto, in the annual report of the Board to Congress, though reference is made later on in this report to several matters upon which action was taken at that meeting.

It becomes my sad duty to announce the death of two members of the executive committee of the Board of Regents during the year, Dr. Welling, on September 4, 1894, and Dr. Coppée, on March 21, 1895. I give sketches of their lives and work on subsequent pages devoted to necrology.

On February 27, 1895, Mr. Gardiner G. Hubbard, of Washington City, was appointed a Regent by joint resolution of Congress.

The term of office of Senator Cullom expired with his term as Senator on March 4, 1895.

ADMINISTRATION.

The expenses borne by the Institution, incidental to its administration of Government trusts, are increasing so rapidly that I feel it my duty to again call attention to the subject, though it has been mentioned at greater or less length in all of my recent reports. The expenses that I refer to are not specifically provided for by any of the present appropriations, since they belong, not singly to the National Museum, or to the Bureau of Ethnology, or to the International Exchange Service, or the like, but to expenditures common to all of them. I deem it in the interest of economy that an appropriation be asked to cover these items, for it seems manifest that this expenditure should be met from some common source, owing to the limited size of the establishments in question, some of which are rather assimilable to divisions than to bureaus. It is evident, for instance, that an appropriation of $17,000 for international exchanges or an appropriation of $10,000 for an observatory can not each so well bear the separate provision of a disbursing officer, a stenographer, and the other like employees as in the case of larger bureaus. There is, however, no practicable way of arranging this in accordance with the present terms of the appropriations, which may be said to tacitly assume that each of these bureaus or divisions is thus completely provided for. It is in some cases impossible that it should be so without the expenditure of much more than the appropriated sum, and the terms of the appropriations should, in the interest of economy, either recognize the propriety of meeting each bureau's share of these common expenses out of each one's appropriation, or else out of a special appropriation made in their common interest.

FINANCES.

The permanent funds of the Institution are as follows:

Bequest of Smithson, 1846	$515,169.00
Residuary legacy of Smithson, 1867	26,210.63
Deposits from savings of income, 1867	108,620.37
Bequest of James Hamilton, 1875	1,000.00
Bequest of Simeon Habel, 1880	500.00
Deposits from proceeds of sale of bonds, 1881	51,500.00
Gift of Thomas G. Hodgkins, 1891	200,000.00
Portion of residuary legacy, Thomas G. Hodgkins, 1894	8,000.00
Accumulated interest on Hamilton fund, 1895	1,000.00
Total permanent fund	912,000.00

The Regents also hold certain approved railroad bonds, forming a part of the fund established by Mr. Hodgkins for investigations of the properties of atmospheric air.

By act of Congress approved by the President March 12, 1894, an amendment was made to section 5591 of the Revised Statutes, the fundamental act organizing the Institution, as follows:

The Secretary of the Treasury is authorized and directed to receive into the Treasury, on the same terms as the original bequest of James Smithson, such sums as the Regents may, from time to time, see fit to deposit, not exceeding, with the original bequest, the sum of $1,000,000: *Provided*, That this shall not operate as a limitation on the power of the Smithsonian Institution to receive money or other property by gift, bequest, or devise, and to hold and dispose of the same in promotion of the purposes thereof.

Under this section 5591 of the Revised Statutes, modified as above noted, the fund of $912,000 is deposited in the Treasury of the United States, bearing interest at 6 per cent per annum, the interest alone being used in carrying out the aims of the Institution.

At the beginning of the fiscal year, July 1, 1894, the unexpended balance from the income and from other sources, as stated in my report for last year, was $59,598.50. Interest on the permanent fund in the Treasury and elsewhere, amounting to $56,153.92, was received during the year, which, together with a sum of $6,074.38, received from the sale of publications and from miscellaneous sources, made the total receipts $62,228.30.

The entire expenditures during the year, including the $1,000 accumulated interest on the Hamilton fund, mentioned above, which was added to the permanent fund, amounted to $58,825.06, for the details of which reference is made to the report of the executive committee. On June 30, 1895, the balance in the Treasury of the United States to the credit of the secretary for the expenses of the Institution was $63,001.74, which includes the sum of $10,000 referred to in previous reports, $5,000 received from the estate of Dr. J. H. Kidder, and a like sum from Dr. Alexander Graham Bell, the latter a gift made personally

to the secretary to promote certain physical researches. This latter sum was, with the donor's consent, deposited by the secretary to the credit of the current funds of the Institution.

This balance also includes the interest accumulated on the Hodgkins donation, which is held against certain contingent obligations, besides relatively considerable sums held to meet obligations which may be expected to mature as the result of different scientific investigations or publications in progress.

The Institution has been charged with the disbursement, during the fiscal year 1894–95, of the following appropriations:

For international exchanges	$17,000
For North American Ethnology	40,000
For United States National Museum:	
Preservation of collections	143,000
Furniture and fixtures	10,000
Heating and lighting	13,000
Postage	500
Repairs to building	4,000
Rent of workshops and transfer of property	1,000
Rent of workshops	600
For National Zoological Park	50,000
For Astro-physical Observatory	9,000

All the vouchers and checks for the disbursements have been examined by the executive committee, and the expenditures will be found reported in accordance with the provisions of the sundry civil acts of October 2, 1888, and August 5, 1892, in a letter addressed to the Speaker of the House of Representatives.

The vouchers for all the expenditures from the Smithsonian fund proper have been likewise examined and their correctness certified to by the executive committee, whose statement will be published, together with the accounts of the funds appropriated by Congress, in that committee's report.

The estimates for the fiscal year ending June 30, 1896, for carrying on the Government interests under the charge of the Smithsonian Institution, and forwarded as usual to the Secretary of the Treasury, were as follows:

International exchanges	$23,000
North American Ethnology	50,000
National Museum:	
Preservation of collections	180,000
Furniture and fixtures	30,000
Heating and lighting	15,000
Postage	500
Galleries	8,000
Repairs to building	8,000
National Zoological Park	75,000
Astro-physical Observatory	10,000
Fire protection, Smithsonian Institution and National Museum	800

BUILDINGS.

On a subsequent page I again call attention to the excessively over-crowded condition of the National Museum building and to the necessity of continuing the use of several wooden sheds adjacent to the Smithsonian building for storage purposes, constituting a constant menace to the safety of the main building and its contents. I can give no more adequate idea of the real danger from fire that here exists than by stating that no insurance company was found willing to place insurance upon these sheds or their contents at less than ten times the ordinary rates. The provision made by the last Congress for rent of additional storage rooms proves inadequate for the needs of the Museum, as I have represented elsewhere.

REPAIRS TO THE SMITHSONIAN BUILDING.

In continuing much needed improvements in the east wing of the Smithsonian building, especially with a view to better light and ventilation, the lighting of the rooms on the first floor occupied by the library, has been greatly improved by enlarging the window frames and replacing the small diamond panes by single sheets of glass. Similar changes have been made in the Secretary's office, on the second floor, as well as in some of the rooms on the third and fourth floors. Several rooms on the fourth floor, heretofore of no use except for storage, have been made habitable and have proved useful for various needed purposes.

The sanitary condition of the building has been improved by the removal of certain objectionable features and by the installation of a comprehensive system of ventilation by which pure air at an equable temperature is assured in most of the office rooms. Work upon this was well advanced at the close of the year.

Another great improvement added during the year is the introduction of electric lights in all the offices of the east wing, the electric power being supplied by a special plant, which, with the ventilating apparatus, has been placed in the basement of the south tower, where considerable changes were made for their accommodation.

For the proper heating and ventilation of the Astro-physical Observatory a dry-air duct has been built connecting the observatory with the systems of the main building.

These minor repairs which I have thus briefly mentioned have made the rooms of the east wing much better adapted to use as offices.

RESEARCH.

In pursuance of what appears to be an essential portion of the original plan for the organization of the Institution, that its secretary should be expected to personally contribute to the advancement of knowledge, whether in letters or in science, I have given such time as

I could spare from engrossing administrative duties to the prosecution of two independent investigations which had engaged my attention for several years before I became connected with the Institution, and which I believe are likely to lead to important scientific and utilitarian results. The first of these researches, that upon the solar spectrum, has been carried on in the Astro-physical Observatory, and to it I have referred more at length in the account of the observatory. The second research, an investigation of certain physical data of aerodynamics, has been continued with results which appear to be approaching the time of publication.

Prof. E. W. Morley's investigations on the density of oxygen and hydrogen, referred to in previous reports as aided in part by the Institution, have been completed, and his memoir is now in press. The atomic weight of oxygen may be called the base upon which practically our entire system of atomic weights rests, and a small error in its measurement becomes large by multiplication in the higher parts of the atomic-weight scale. Hence its accurate determination is of fundamental importance. In his investigation Professor Morley has studied the problem by two methods:

(1) By the synthesis of water, in which he, for the first time, has achieved completeness by actually weighing the hydrogen, the oxygen, and the water formed, whereas all his predecessors took one or another of these factors by difference.

(2) By the density ratios between oxygen and hydrogen. In this method he has weighed the gases of greater purity and in larger quantity than hitherto, and he has in some instances operated without the intervention of stopcocks, and therefore with no possibility of error due to leakage. He has also, as a correction to the density ratio, redetermined the composition of water by volume.

By both methods he reaches the same result: $O=15.879$, with variation in the fourth decimal place as between the two.

The valuable balance purchased for these investigations has been returned to the Institution.

The subscription has been continued for 20 copies of the Astronomical Journal as a slight aid to its publication, the separate numbers of the journal being sent regularly to foreign libraries and observatories as exchanges of the Institution.

A small grant was made to Dr. Carl Barus to enable him to continue certain investigations.

The researches that I have here referred to are connected altogether with the physical sciences. In the biological sciences I may refer to the work of the occupants of the Smithsonian table at Naples, though the Institution's work in this field has been largely indirectly provided through its connection with the National Museum. Investigations aided by the Hodgkins fund are mentioned elsewhere.

EXPLORATIONS.

The Institution has carried on some interesting ethnological and natural-history explorations during the year, as noticed in detail on other pages in the reports on the National Museum and the Bureau of Ethnology.

I will here call special attention to the benefit that has been derived from the explorations made by Dr. William L. Abbott and by Mr. William Astor Chanler and Lieut. von Höhnel in Africa and India. Many valuable ethnological and natural-history objects which they have collected on these expeditions have been courteously placed in the National Museum as additions to the collection they had previously contributed.

In the Azores Prof. William Trelease has gathered some interesting natural-history specimens.

Lieut. Wirt Robinson, U. S. A., has made large collections of mammals and pottery in Florida, and Mr. Mark B. Kerr has contributed a collection of fossils from Ecuador.

Explorations have been continued among the aboriginal villages in northeastern Arizona. Some particularly interesting explorations were made in Arizona and Sonora (Mexico) among the Papago and Seri Indians, where a number of prehistoric ruins were discovered with extensive irrigation works, and studies were made of the arts and customs of those hitherto little-known Indians.

Ethnological researches were also carried on among the Kathlamet Indians of the lower Columbia region and among the Kiowa and other plains Indians in Indian Territory.

Explorations begun during May in the Red Rock country, southwest of Flagstaff, Ariz., by Dr. J. Walter Fewkes, as a part of the work of the Bureau of Ethnology, have resulted in the discovery of a group of extensive cliff ruins hitherto unknown to archæologists and not despoiled by white men, and excavations in that region were in progress at the close of the fiscal year.

PUBLICATIONS.

The plan of organization adopted by the Regents in 1847 contemplated the publication of a series of reports giving an account of the new discoveries in science and of the changes made from year to year in all branches of knowledge not strictly professional, and a second series of separate treatises on subjects of general interest, consisting of valuable memoirs translated from foreign languages, or of articles prepared under the direction of the Institution.

Three series of publications have actually been established, the Contributions to Knowledge, the Miscellaneous Collections, and the Annual Reports, the first two being printed at the expense of the Institution, while the reports are Government documents. The Institution also

issues various publications through the National Museum and the Bureau of Ethnology.

Contributions to Knowledge.—No memoir of the Contributions to Knowledge was completed during the present year, though two papers now in type will be published early in the next fiscal year—one of these is a memoir by Professor Morley on the densities of oxygen and hydrogen, and the second a report by Drs. J. S. Billings, S. Weir Mitchell and D. H. Bergey on investigations carried on by them, under a grant from the Hodgkins fund, to determine the nature of supposed poisonous properties of expired air.

It was hoped that during the year two elaborate memoirs, on "Oceanic ichthyology" and on "Life histories of North American birds," mentioned in my last report, would be published, but they are not yet completed, though they are entirely ready for presswork.

Miscellaneous Collections.—Five papers of this series were issued during the year, besides separates of the several scientific papers contained in the General Appendix of the Annual Report.

In connection with the system of meteorological observations established by the Smithsonian Institution about 1850, a series of meteorological tables was compiled by Dr. Arnold Guyot, at the request of Secretary Henry, and was published in 1852. A second edition was issued in 1857, and a third edition, with further amendments, in 1859. Though primarily designed for meteorological observers reporting to the Smithsonian Institution, the tables were so widely used by physicists that, after twenty-five years of valuable service, the work was again revised and a fourth edition was published in 1884. In a few years the demand for the tables exhausted the edition, and it appeared to me desirable to recast the work entirely, rather than to undertake its revision again. After careful consideration I decided to publish a new work in three parts—Meteorological Tables, Geographical Tables, and Physical Tables—each representative of the latest knowledge in its field, and independent of the others, but the three forming a homogeneous series. Although thus historically related to Dr. Guyot's Tables, the present work is so entirely changed with respect to material, arrangement, and presentation that it is not a fifth edition of the older tables, but essentially a new publication.

The first volume of the new series of Smithsonian Tables (the Meteorological Tables) appeared in 1893, and so great has been the demand for it that a second edition has already become necessary. The second volume of the series (the Geographical Tables) was published during this year. It was prepared by Prof. R. S. Woodward, formerly of the United States Coast and Geodetic Survey, but now of Columbia College, New York.

The manuscript of the Physical Tables, prepared by Prof. Thomas Gray, has been sent to the printer and some progress made toward its publication. This work will form the third volume of Smithsonian Tables.

In continuation of the series of indexes to chemical literature, prepared under the direction and on the recommendation of a committee of the American Association for the Advancement of Science, three additional pamphlets have been issued, entitled Indexes to the Literatures of Cerium and Lanthanum, by W. H. Magee, Ph. D.; Index to the Literature of Didymium, by A. C. Langmuir, Ph. D.; and Bibliography of Aceto Acetic Ester, by Paul H. Seymour, M. S.

One of the treatises in the Miscellaneous Collections published during the year, entitled The Varieties of the Human Species, by Giuseppe Sergi, a translation of that author's work, Le Varietà Umane, Principi e metodo di Classificazione, Torino, 1893, sets forth quite fully his doctrines of craniology, elaborating a plan for a classification of human species based on shapes of the crania.

As a special publication of the Institution there was issued a Diary of a Journey through Mongolia and Tibet in 1891 and 1892, by Mr. William Woodville Rockhill. It is an octavo volume of 443 pages, illustrated by 13 text figures and 28 plates, together with a large map on a scale of 32 miles to the inch, showing the route traversed and the topographic features of those little-known regions. The journey was undertaken partly under the auspices of the Smithsonian Institution. In addition to much valuable information gathered concerning the characteristic features of those countries, Mr. Rockhill made some very interesting ethnological collections for the National Museum, which are described in detail in one of the accompanying papers of the Museum Report for 1893.

A revised edition of the Catalogue of Scientific and Technical Periodicals (1665–1882), published by the Institution in 1885, is being prepared under the direction of Dr. H. C. Bolton. In this new work the periodicals in the former edition will be continued to 1895, and new publications will be added, making the catalogue as near as possible complete to the time of printing.

A supplement to the Bibliography of Chemistry, 1492–1892, published in 1893, is being prepared by Dr. Bolton, with the assistance of several collaborators in European libraries, and will bring the work down as near as practicable to date.

Annual Reports.—The Smithsonian Annual Report is the only public document published by the Institution, and the greater portion of the edition is distributed through the document rooms of the Senate and House of Representatives. It is in two volumes—the first devoted to the Institution proper and the second part relating to the National Museum. The General Appendix of Part I consists of selected memoirs of a special interest and permanent value which have, for the most part, already appeared elsewhere, and which are sufficiently untechnical to be interesting to the general reader.

The Annual Report of the Institution for 1893 and of the National Museum for 1892 were received from the Public Printer and distributed during the year, and the Museum report for 1893 was nearly completed.

The manuscript of both volumes of the report for 1894 has been sent to the printer, and some progress made toward their publication.

The secretary's report for the year ending June 30, 1894, was submitted in printed form to the Board of Regents at their January meeting.

Proceedings and bulletin of the National Museum.—The publications of the Museum are discussed on another page, and therefore need no reference here other than to mention that there were issued fifty-six separate papers of the proceedings, chiefly on natural-history subjects, and one number of the bulletin series, of interest chiefly to entomologists.

Bureau of Ethnology publications.—The eleventh and twelfth annual reports of the Bureau of Ethnology were published during the year, and the thirteenth report was put in type, while the manuscript of the fourteenth and fifteenth reports have been sent to the printer, thus bringing the work practically to date. The contents of the published volumes, as also mention of several papers of the bulletin series, are discussed on subsequent pages.

LIBRARY.

The growth of the library steadily continues, 31,953 titles having been added during the past year. Among the more notable accessions, I may mention a collection of albums of photographs presented by the Sultan of Turkey, which portray the natural scenery, the art, education, industries, and government of the Ottoman Empire.

It has been possible to improve the light in the reading room of the library offices and to assign another small room to the library, and a small collection of wholesome popular literature has been commenced for the use of the employees of the Institution.

The results of the plan to increase the library by exchange, detailed in my report for 1887–88, have been carefully tabulated with a view to the completion of incomplete sets of periodicals and the publications of learned societies, and to further additions to the already large list.

This plan has thus far, after seven years' labor, secured for the Institution 2,035 new periodicals and the entire or partial completion of 1,133 defective series.

The tabulation shows that the Institution now possesses 869 complete sets of foreign publications and 395 of American publications, while 888 sets of foreign publications and 569 sets of American publications are as complete as the publishers are able to make them.

The collection of scientific and other periodicals possessed by the Institution is now probably the largest in the English-speaking world—numbering, approximately, 4,000. Many of these are no longer published, and in some cases the exchange is discontinued. At present there are currently received 3,045; of these, 1,372 are in the English language, 621 in German, and 423 in French, the remainder representing almost all the languages of civilized nations, and including publi-

cations even in modern Greek, Japanese, and Arabic. There are 825 annuals, 397 quarterlies, 670 monthlies, and the remainder are issued at different intervals or irregularly. A portion are for the present retained for reference, but are ultimately designed for the Smithsonian deposit at the Library of Congress. It is my desire that the Institution shall keep abreast of the ever-growing number of scientific periodicals and journals and of the publications of societies cultivating the various branches of science. The work is never ending, and the preparation of new lists and correspondence for exchange and revision are constantly going on.

The time is now not far distant when an adequate provision will be made for the major portion of the Smithsonian library, which is, in accordance with the act of 1865, deposited with the Library of Congress. The Librarian of Congress states that the Smithsonian library will be arranged in a separate stack of the new building, now completed and rapidly approaching the time when it will be habitable, and that a special reading room, convenient to the main reading room and the stack, will be provided. It may be suitable to mention, in connection with the library, the fact that the Institution is now, as it has been from its inception, heartily interested in the publication of bibliographical memoirs and in the general subject of the bibliography of science.

During the past year I have been informed of a project of the Royal Society for the preparation of a bibliography of science, beginning with the year 1900, and some correspondence on this important subject has taken place between the Royal Society and the Institution. At the present writing no definite result has been reached.

HODGKINS FUND.

It is gratifying to the Institution to note the wide interest taken in the Hodgkins fund prizes which were offered for certain essays upon the properties of atmospheric air, in accordance with the wishes of the donor of the fund, Mr. Thomas G. Hodgkins.

The recent discoveries made upon the composition of atmospheric air have been most important, and researches now in progress seem to promise still further additions to the knowledge of our atmosphere.

It will be remembered that three prizes were offered—one for $10,000, one for $2,000, and one for $1,000; the terms of competition being stated in a circular issued by the Institution in 1893 and printed in full in my report for that year.

For reasons stated in a circular issued in June, 1894, the time for submitting memoirs in competition for the Hodgkins fund prizes was extended from July 1 to December 31, 1894, and resulted in a considerable increase in the number of papers, so that the total number up to December 31, 1894, was 218.

It is interesting to note the various countries that participated in this competition: the United States contributing 66 memoirs, France

40, Germany 33, England 19, Italy 8, Russia 6, Austria-Hungary 9, and Denmark 4; the other countries represented were Belgium, Scotland, Ireland, Norway, Bohemia, Finland, Spain, Bavaria, Switzerland, Servia, India, Canada, Mexico, and Argentina.

As soon as the competition was closed the following circular was sent to all participants, and was published in several of the leading scientific journals:

SMITHSONIAN INSTITUTION.

HODGKINS PRIZES.

WASHINGTON, *January 10, 1895.*

SIR: The time for the reception of treatises or essays offered in competition for the Hodgkins fund prizes of $10,000, of $2,000, and of $1,000, respectively, closed on the 31st of December, 1894, and all papers so offered are now in the hands of the committee of award.

In view of the very large number of competitors, of the delay which will be necessarily caused by the intended careful examination, and of the further time which may be required to consult a European advisory committee, if one be appointed, it is announced that authors are now at liberty to publish these treatises or essays without prejudice to their interest as competitors.

Very respectfully,

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

The circular was also issued in French, as follows:

INSTITUT SMITHSONIEN.

PRIX HODGKINS.

WASHINGTON, *le 10 janvier 1895.*

MONSIEUR: Le terme fixé pour la réception des traités ou des essais soumis au concours du fonds Hodgkins, pour les prix de 10,000, 2,000, et 1,000 dollars, est expiré le 31 décembre 1894 et tous les ouvrages présentés sont actuellement entre les mains de la commission des récompenses.

En raison du très-grand nombre de concurrents, du délai qu'entraînera l'examen sérieux que l'on compte faire, et du temps qui pourrait être exigé pour prendre l'avis du comité consultatif d'Europe, s'il en est nommé un, il est donné avis que ces traités ou essais pourront maintenant être publiés par leurs auteurs en toute liberté et sans que leurs intérêts de concurrents en soient atteints.

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

The committee of award was composed of Dr. S. P. Langley, chairman, ex officio; Dr. G. Brown Goode, Assistant Secretary of the Smithsonian Institution; Asst. Surg. Gen. John S. Billings, United States Army; and Prof. M. W. Harrington, Chief of the United States Weather Bureau.

The foreign advisory committee was represented by Mons. J. Janssen, Prof. T. H. Huxley, and Professor von Helmholtz; and after the death of the latter, Dr. W. von Bezold was added.

Immediately upon the close of the competition the award committee began examination of the papers, and at the end of the fiscal year had practically completed their labors. Although the awards were not formally announced until August 9, yet in view of the importance and opportuneness of the subject it seems proper to include the committee's report in my report for this year.

Report of the committee appointed by the Smithsonian Institution to award the Hodgkins fund prizes.

The committee of award for the Hodgkins prizes of the Smithsonian Institution has completed its examination of the 218 papers submitted in competition by contestants.

The committee is composed of the following members:

Dr. S. P. Langley, chairman, ex-officio; Dr. G. Brown Goode, appointed by the Secretary of the Smithsonian Institution; Asst. Surg. Gen. John S. Billings, by the president of the National Academy of Sciences; Prof. M. W. Harrington, by the president of the American Association for the Advancement of Science.

The foreign advisory committee, as first constituted, was represented by Mons. J. Janssen, Prof. T. H. Huxley, and Professor von Helmholtz; and after the recent loss of the latter, Dr. W. von Bezold was added. After consultation with these eminent men, the committee decided as follows:

First prize, of $10,000, for a treatise embodying some new and important discoveries in regard to the nature or properties of atmospheric air, to Lord Rayleigh, of London, and Prof. William Ramsay, of the University College, London, for the discovery of argon, a new element of the atmosphere.

The second prize, of $2,000, is not awarded, owing to the failure of any contestant to comply strictly with the terms of the offer.

The third prize, of $1.000, to Dr. Henry de Varigny, of Paris, for the best popular treatise upon atmospheric air, its properties and relationships. Dr. de Varigny's essay is entitled "L'Air et la Vie."

S. P. Langley.
G. Brown Goode.
J. S. Billings.
Mark W. Harrington.

Washington, *August 9, 1895.*

Supplementary report of the committee appointed by the Smithsonian Institution to award the Hodgkins fund prizes.

After having performed the function to which the committee was called, as announced by the circular of the secretary of the Smithsonian Institution, dated March 31, 1893, which function did not include the award of any medals, there remained several papers to which the committee had been unable to give any prize, but to which they had felt desirous to give some honorable mention, and on their representing this to the Smithsonian Institution, they have been commissioned to do so and also to give certain medals of silver and bronze which had been subsequently placed at their disposition.

The committee has decided that honorable mention should be made of the papers, twenty-one in number, included in the following list, which also gives the full names, titles, and addresses of the authors and

the mottoes or pseudonyms which in four instances were employed. To three of the papers a silver medal is awarded, and to six a bronze medal:

Honorable mention with silver medal.—Prof. A. L. Herrera and Dr. Vergara Lopez, of the City of Mexico, "La Atmosfera de las altitudes y el bienstar del hombre;" Mr. C. L. Madsen ("Geo") Helsingör, near Copenhagen, Denmark, "Thermogeographical studies;" Mr. F. A. R. Russell, of London, vice-president of the Royal Meteorological Society of Great Britain, "The atmosphere in relation to human life and health."

Honorable mention, with bronze medal.—M. E. Deberaux-Dex and M. Maurice Dibos ("Spes"), of Rouen, France, "Études des courants aériens continentaux et de leur utilisation par des aérostats long-courriers;" Dr. O. Jesse, of Berlin, "Die leuchtenden Nachtwolken;" Dr. A. Loewy, of Berlin, "Untersuchungen über die Respiration und Cirkulation unter verdünnter und verdichteter sauerstoffarmer und saerstoffreicher Luft;" Mr. Alexander McAdie ("Dalgetty"), of Washington, "The known properties of atmospheric air considered in their relationships to research in every department of natural science, and the importance of a study of the atmosphere considered in view of these relationships; the proper direction of future research in connection with the imperfections of our knowledge of atmospheric air and the conditions of that knowledge with other sciences:" Mr. Hiram S. Maxim, of Kent, England, "Natural and artificial flight;" Dr. Franz Oppenheimer and Dr. Carl Oppenheimer ("E pur si muove"), of Berlin, "Ueber atmosphärische Luft, ihre Eigenschaften und ihren Zusammenhang mit dem menschlichen Leben."

Honorable mention.—Mr. E. C. C. Baly, of University College, London, "The decomposition of the two constituents of the atmosphere by means of the passage of the electric spark;" Prof. F. H. Bigelow, of Washington, "Solar and terrestrial magnetism and their relation to meteorology;" Dr. J. B. Cohen, of Yorkshire College, Leeds, England, "The air of towns;" Dr. F. J. B. Cordeiro. U. S. N., of Washington, "Hypsometry;" Prof. Emile Duclaux, of the French Institute, Paris, France, "Sur l'actinométrie atmosphérique et sur la constitution actinique de l'atmosphère;" Professor Doctor Gieseler, of Bonn, Germany, "Mittlere Tagestemperaturen von Bonn, 1848–1888;" Dr. Ludwig Ilosvay von Nagy Ilosva, professor in the Royal Joseph Polytechnic School, Budapest, Hungary, "Ueber den unmittelbar oxydirenden Bestandtheil der Luft;" Dr. A. Magelssen, of Christiania, Norway, "Ueber den Zusammenhang und die Verwandschaft der biologischen, meteorologischen und kosmischen Erscheinungen;" Dr. A. Marcuse, of the Royal Observatory, Berlin, "Die atmosphärische Luft;" Prof. C. Nees, of the Polytechnic School, Copenhagen, Denmark, "The use of kites and chained air balloons for observing the velocity of winds, etc.;" Surg. Charles Smart, U. S. A., of Washington, "An essay on the properties, constitution, and impurities of atmospheric air, in relation to the promotion of health and longevity;" Dr. F. Viault, of the Faculty of Medicine, Bordeaux, France, "Découverte d'une nouvelle et importante propriété physiologique de l'air atmosphérique. (Action hématogene de l'air raréfié)."

S. P. LANGLEY.
G. BROWN GOODE.
J. S. BILLINGS.
MARK W. HARRINGTON.

WASHINGTON, *August 9, 1895.*

Immediately after the announcement of the award of the first prize to Lord Rayleigh and Professor Ramsay, of London, for their discovery of "argon," an element of the atmosphere, a draft for $10,000 was despatched to these gentlemen, through the courtesy of the Department of State, and of the Hon. Thomas F. Bayard, United States ambassador to Great Britain.

With regard to other work carried on by the Hodgkins fund, I may state that Dr. J. S. Billings and Dr. S. Weir Mitchell have completed the investigations begun by them in 1893, under a grant from the Hodgkins fund, to determine the nature of the peculiar substances of organic origin contained in the air expired by human beings, and their report is now in press.

In their report the investigators state that for a number of years prior to 1888 the prevailing view among physicians and sanitarians had been that the discomfort and dangers to health and life which had been known to exist, sometimes at least, in unventilated rooms occupied by a number of human beings were largely or entirely due to peculiar organic matters contained in air expired by these persons, and that the increase in carbonic acid due to respiration had but little effect in producing these results, its chief importance being that it furnished a convenient means of determining the amount of vitiation of the air. Recently, however, several experimenters have concluded that the organic matters in the exhaled breath are not harmful, at all events to animals, and the main object of the investigations was to determine the correctness of these conclusions.

The investigators found that the air in inhabited rooms, such as the hospital ward in which experiments were made, is contaminated from many sources besides the expired air of the occupants, and that the most important of these contaminations are in the form of minute particles or dust, in which there are micro-organisms, including some of the bacteria which produce inflammation and suppuration. It is probable that these dust particles were the only really dangerous elements in the air, and it appears improbable that there is any peculiar volatile poisonous matter in the air expired by healthy men and animals other than carbonic acid.

In concluding their report the authors state that the results of the investigations, taken in connection with the results of other researches summarized in the report, indicate that some of the theories upon which modern systems of ventilation are based are either without foundation or doubtful, and that the problem of securing comfort and health in inhabited rooms requires the consideration of the best methods of preventing or disposing of dusts of various kinds, of properly regulating temperature and moisture, and of preventing the entrance of poisonous gases like carbonic oxide derived from heating and lighting apparatus, rather than upon simply diluting the air to a certain standard of proportion of carbonic acid present.

The work of Dr. O. Lummer and Dr. E. Pringsheim, under a grant from the Hodgkins fund, on the determination of an exact measure of the cooling of gases while expanding, with a view to revising the value of that important constant technically termed the "gamma" function, was referred to in my last report.

The limitations of the fund have rendered it necessary, with slight exceptions, to postpone further action on requests for grants, although it is hoped that it will prove practicable at a later date to aid certain important researches which are under consideration.

A design for the Hodgkins fund medal of the Institution was decided upon in May, 1895, and the preparation of the dies has been ordered.

AVERY FUND.

Mr. Robert Stanton Avery, of Washington City, died September 12, 1894, bequeathing the greater portion of his estate to the Smithsonian Institution. The estate has not yet been fully administered upon, and I am therefore unable to state the exact amount of the fund.

CORRESPONDENCE.

Besides the very voluminous routine and business correspondence of the National Museum, or special correspondence of the Bureau of Ethnology, of the Zoological Park, and of the Bureau of Exchanges, a great number of letters come directly to the Secretary's office from all parts of the country, on every imaginable subject that can by any possibility be supposed to have a relation to science. Requests for statistics that may be of great value and importance to the writer, inquiries from teachers and others, are constantly received, and it is still my aim that this correspondence shall receive the same careful attention that was bestowed upon it in the early days of the Institution, when the number of letters received formed but a small fraction of the present number; but it will be understood that the fulfilment of this aim grows increasingly difficult. An effort is made to give a full reply to all such inquiries, often involving a large amount of labor on the part of the curators, as well as of those immediately occupied with the correspondence of the Institution, out of proportion to the merits of the case.

Of the more important correspondence of the Secretary's office, 3,601 entries were made in the registry book of letters received during the year, while double that number of letters were received and referred to the different bureaus of the Institution in the same time. A modification of the system of registry was introduced on January 1, 1895, by which each letter receives an arbitrary number indicating the date of the letter and a subsidiary number giving the order of entry on that day.

The card index of letters received and written is now complete from January 1, 1892, to the present day, constituting the current file. The correspondence prior to the current file has been placed in the archives, and the index to the files is now practically complete.

As I have elsewhere remarked, this work of the Institution could be much expedited, as far as the purely clerical part of it is concerned, were an appropriation available for the general administrative purposes to which I have referred more at length under "Administration."

MISCELLANEOUS.

Naples table.—Dr. J. S. Billings, U. S. A., Dr. E. B. Wilson, Dr. J. A. Ryder, and Dr. C. W. Stiles, as an advisory committee, have continued valuable aid in examining the testimonials of applicants for the occupancy of the Naples table, as well as in the consideration of various questions in connection with the assignment of the table, to which I have asked attention. Dr. Ryder died in April, 1895, and was succeeded on the committee by Dr. Harrison Allen.

The Smithsonian table at the Naples Zoological Station has proved of value to the investigators who have carried on biological studies there during the year.

Among the numerous additional applications for occupancy of the table the following have been favorably acted upon:

Lewis Murbach, Ph. B., B. Sc., University of Michigan; appointed for three months during summer and autumn of 1894.

T. H. Morgan, B. S., Ph. D., Johns Hopkins University; appointed for six months, November 9, 1894, to May 9, 1895.

Herbert Osborn, professor of zoology and entomology, Iowa Agricultural College; appointed for three months in spring and summer of 1894.

The table has been occupied constantly since October 1, 1893, the date of the first appointment, with the exception of May, 1894. In several instances Dr. Dohrn, the director of the station, has courteously arranged for the accommodation of two occupants at the same time.

In order that all investigators may be given an equal opportunity to avail themselves of the facilities for study at Naples, final action upon applications is not taken more than six months in advance of the date for which the table is desired, and when more than one application is filed for the same period, presumably of equal merit, the assignment is made according to priority of application. No appointment is made for a period of more than six months.

The reports thus far submitted by the investigators who have occupied the table indicate an appreciation of the special privileges there offered for study.

Atlanta Exposition.—Under the provisions of an appropriation made by Congress for a Government exhibit at the Cotten States and International Exposition at Atlanta, during the autumn of 1895, a very satisfactory exhibit has been prepared, illustrating every phase of the activities of the Institution and its bureaus, especially the National Museum.

Oriental Congress.—As delegate of the Smithsonian Institution Prof. Paul Haupt attended the Tenth International Congress of Oriental-

ists, held at Geneva, Switzerland, September 3–12, 1894. Besides the Smithsonian the following American institutions and learned societies were represented by delegates: Columbia College, Cornell University, Johns Hopkins University, University of Minnesota, University of Pennsylvania, American Oriental Society, American Philosophical Society, Bureau of Education. The Congress was opened by the President of the Swiss Republic, Colonel Frey. The president of the congress was the well-known Geneva egyptologist, M. Edouard Naville. The work of the congress was organized in eight sections: India, linguistics and Aryan languages, Semitic languages, Mohammedan languages, Egypt and African languages, Extreme East, Greece and the Orient, Oriental geography and ethnography. There were altogether about 600 members (about 100 of whom were ladies), representing Africa, America, Asia, and 16 European countries. More than 275 (about 60 ladies) were present, not including those living at Geneva. Of the 28 American subscribers (including 5 ladies), 12 (4 ladies) attended the congress. Papers were read by the following American members: Haupt, Jackson, Merriam, Rogers.

At the first meeting of the first section the great Sanskrit scholar of the University of Berlin, Prof. A. Weber, referred to the death of Professor Whitney, and the proposition of the president of the section, Lord Reay, to send a resolution of respect and condolence to Mrs. Whitney, was unanimously adopted.

The Eleventh International Congress of Orientalists will be held at Paris in 1897.

Archives.—The special room set apart on the fourth floor for the better arrangement of the valuable archives of the Institution has proved of great convenience, as there is frequent necessity for reference to the early correspondence files, or to other records.

Assignment of rooms.—A room in the basement of the east wing, which has been specially fitted up with piers for pendulum experiments and connected by telegraph, through the Western Union Telegraph Company's office, with the United States Naval Observatory, is still reserved for the occasional use of the officers of the United States Coast and Geodetic Survey.

The Astro-physical Observatory standard clock has been mounted in the room adjoining, where it is protected from sudden changes in temperature and other disturbances to which it would be liable in the observatory building. It can be compared with the Naval Observatory time signals, and provision has been made for transmitting its own signals to any part of the Institution.

History of James Smithson.—Arrangements are in progress for placing bronze tablets on Smithson's tomb and in the English church at Genoa, in memory of the founder of the Smithsonian Institution.

A further English record has added somewhat to the knowledge of Smithson's personal family.

A complete set of the publications of the Institution has been sent to Pembroke College, Oxford, where Smithson received his education.

Portrait of Secretary Baird.—The Board having authorized a portrait of Professor Baird, one has been painted by Mr. Robert Gordon Hardie and placed in the Regents' room of the Institution.

The Hamilton fund.—The original amount of $1,000, the bequest of Mr. James Hamilton, of Pennsylvania, received by the Institution in 1874, has been increased during the year to $2,000 by the addition of accumulated interest, under authority given by the Regents in their meeting of January 23, 1895.

American Historical Association.—The annual report of the American Historical Association for the year 1894 has been transmitted to Congress through the Secretary of the Institution, in accordance with the act of incorporation of the association. These reports are Congressional documents and the Institution has no control of their distribution.

American Medical Association.—A large collection of medical books, which had for many years been in the care of the Institution as the property of the American Medical Association, has been transferred by the association to the Newberry Library in Chicago.

THE NATIONAL MUSEUM.

In my last annual statement I pointed out three conditions which are operating to seriously retard the growth of the National Museum: First, the lack of space for the installation of objects which should be placed on exhibition; second, the unsymmetrical growth of the collections; and third, the fact that the storage of collections in the wooden sheds south of the Smithsonian building, as well as in the basement of the building itself, is most undesirable and dangerous. The sum of $900, allowed for 1896, will be necessarily expended in the rental of shop and storage room in place of the "Armory building." The actually dangerous wooden sheds must therefore remain occupied until a sum of money is provided which will enable me to discontinue their use altogether by renting other quarters, removed entirely from proximity to the Smithsonian building.

The problem of even providing shelter of any kind for the vast amount of material daily received from persons interested in the growth and work of the Museum, still remains unsolved. The Institution is placed in an embarrassing position. It has been designated by law as the only depository of collections offered to, or made under the auspices of, the Government, and can not, under the law, refuse to receive them. The fact remains, however, that when accepted, there is no suitable place in which to store them, and no space in the Museum building to exhibit such of the objects as should properly be shown to the public. As I have already pointed out, there is probably no museum in the world in which so small a proportion of the objects worthy of exhibition is visible to the public, or in which the objects exhibited are crowded

together so closely. It is now more true than ever that if another museum building as large as the present one were provided, it could be at once filled with specimens already on hand.

In my estimates to Congress I have frequently dwelt upon the need of larger appropriations for the preservation of the collections, but regret to say that no substantial increase has yet been made. Indeed, the amount recently appropriated for the coming year (1895–96) is nearly $2,000 less than for 1892, although the accessions since that time have already amounted to more than 375,000 specimens. In my estimates for 1897, recently submitted to the Secretary of the Treasury, I placed stress upon the fact that the purchase of collections is now essential for the completion of large and important series, the deficiencies in which can not be supplied in any other way. Valuable collections which should by all means be acquired by the United States for its National Museum are every year passing beyond our control, and American students will be compelled more than in the past to pursue their researches in the museums of foreign countries.

I desire to repeat that an unduly large proportion of the curators are not compensated for their services from the Museum appropriation. This is not as it should be, although without larger appropriations it is impossible to make any additions to the salaried staff. Many on the clerical force, too, who have by long training become valuable, are paid at rates considerably less than for similar services in the Executive Departments, and it is difficult to keep the force in effective condition on this account.

The resources of the Museum have been taxed to the utmost to provide cases for the collections, but the amount appropriated is altogether inadequate. The sum of $10,000 which was allowed for the present year (1895) is not sufficient for the construction of new cases and for repairing old ones. I am therefore about to submit an estimate of $30,000 for the year 1897. It not unfrequently happens that valuable collections are offered to the Museum on condition that suitable cases be provided. This seems a fair requirement, but it is one which unfortunately the Museum is not always in a position to meet.

With a view to adding to the area available for the display of collections, I included in my estimates for this year (1895) an item of $8,000 for the erection of two galleries, one in the southwest court, and another in the southeast range. Galleries were provided for in the original plans for the Museum building, and can be supported so as not to detract from the appearance of the halls or to interfere with the present system of installation. No appropriation, however, was made. The same amount was included for this purpose in the estimates for 1896, but was again refused. I shall repeat the recommendation in my estimates for 1897.

By the provisions of the new printing bill, as interpreted by the Public Printer, the editions of the Proceedings and Bulletins of the Museum

have been reduced to 1,000 copies. This is most unfortunate, and unless relief is obtained at once, will cause the suspension of the greater part of the distribution of those volumes. It has hitherto been possible to supply 2,300 of the most important libraries and about 500 specialists with our publications, but unless the former number of copies is again allowed, very little can be done in either direction. Furthermore, the possibility of securing in exchange the publications of other institutions, will be almost entirely removed. It is often possible to acquire valuable specimens in exchange for publications, even when the owners would not part with them for a money consideration. Papers of great scientific value are not unfrequently offered to the Museum for publication, but it is now becoming necessary to decline to publish them, as their acceptance would swell the cost of the annual printing for the Museum to a sum far beyond the present allotment. Many important papers published by the Museum are out of print, and should at once be reprinted to supply the urgent demand, but this can not be done without a larger appropriation.

It is not too much to say that the usefulness of the Museum will be considerably impaired if the editions are not at least increased to their former extent, namely, 3,000 copies. The relations of the Museum with the colleges, scientific schools, scientific and technical societies in the United States, as well as with the principal centers of learning throughout the world, will be impaired. It should be borne in mind that the publications of the Museum are not "public documents," so that the possibility of obtaining the usual increase of copies is precluded, none others being printed excepting those which are actually paid for from the Museum allotment for labels, Proceedings, and Bulletins. In view of these facts I can not too strongly urge that the National Museum be excepted from the restrictions of the printing act of January 12, 1895, so far as the extent of the editions of its publications is concerned, and that it be permitted to issue as large an edition both of Proceedings and Bulletins as can be procured out of the Museum allotment. I have asked for $18,000 for the year 1897, and am quite confident that this is not by any means too large for the purpose. It is my belief that if this amount be allowed—and provided that the Museum be removed from the restriction of the printing act in this particular—the number of copies can be increased to 5,000. This would enable the Museum to meet its obligations, and to use a fair proportion of its publications in exchange for specimens as well as for the publications of other scientific institutions.

In recognition of services being rendered to the Museum the honorary title of "Associate" has been conferred on Dr. Theodore N. Gill, in zoology, Dr. R. E. C. Stearns, in zoology, Dr. R. W. Shufeldt, in comparative anatomy, and Dr. C. A. White, in paleontology.

By act of Congress approved August 18, 1894, the Smithsonian Institution and the National Museum were directed to participate in

the Cotton States and International Exposition in Atlanta, commencing September 18 and closing December 31, 1895. With this in view it became necessary for many of the curators to devote a large share of the year to the preparation of suitable exhibits. A description of these will accompany the report of the Assistant Secretary for 1896.

Large and important accessions have been received, as usual, from the United States Geological Survey, the Department of Agriculture, the Bureau of Ethnology, and the U. S. Fish Commission.

It is gratifying to note that Dr. William L. Abbott and Mr. William Astor Chanler and Lieut. von Höhnel have continued to contribute valuable collections of ethnological and natural history objects, obtained in connection with their respective explorations in Africa and India. The Museum still enjoys the cooperation of several officials of the Geological Survey, the Department of Agriculture, and the Fish Commission as honorary curators of collections.

About 127,000 specimens have been added to the collections during the year. In view of the fact that no special effort has been made to acquire material, this large addition would be very gratifying if the conditions were such that it were possible to administer it properly.

In the Appendix accompanying this report some of the most important operations of the Museum during the year are briefly referred to. The report of the Assistant Secretary in charge of the National Museum, constituting the second volume of the Smithsonian Report, discusses fully the work of the Museum during the year.

BUREAU OF AMERICAN ETHNOLOGY.

The researches upon the ethnology of the American Indians have been carried forward, as heretofore, under the direction of Maj. J. W. Powell. As in previous years, a certain amount of field exploration has been carried on. Especially interesting have been the results of the expedition in the arid region in Arizona and Sonora, Mexico, known as Papagueria, lying south of the Gila River, west of the Sierra Madre. The region first visited was that occupied by the Papago Indians; nearly all of their villages and rancherias were examined and a number of prehistoric ruins were discovered, among them those of villages with extensive irrigation works. Subsequently was visited the domain of the Seri Indians, occupying Tiburon Island in the Gulf of California, and a considerable region of the adjacent mainland in western Sonora.

The Papago Indians are peaceful and represent the higher grade of aboriginal intelligence among the inhabitants of Mexico and Central America; the Seris are savage and primitive in their habits, being probably the least advanced of the North American tribes still remaining. The archæological results of the collections obtained are of special interest, since the region is very peculiar and but partially known.

The surveys in the Canyon de Chelly, referred to in previous reports, were completed during the year, and an account of the work will soon

be published, which it is hoped will be an important contribution to our knowledge of the origin and early history of the cliff dwellings and pueblos of the Southwest.

Experts have also been engaged in the Indian Territory during the year investigating the heraldic systems and the calendars of the Kiowa Indians. Toward the close of the year a special expedition was sent to excavate the ruins of the pueblos in the little-known country southwest of Flagstaff and at Tusayan, in northeastern Arizona. This section was under the charge of Dr. J. Walter Fewkes, and the results, so far as reported, have been exceedingly important.

The death of Col. Garrick Mallery interrupted for the time the work of the Bureau in the investigation of Indian sign languages. The study of the Mexican codices and inscriptions has been continued, and an important paper on the Maya year has been published.

As during previous years, especial attention has been paid to the study of myths, beliefs, and ceremonials, especially those of the Zuni Indians, who are particularly interesting by reason of the important part played by mythology in their organizations.

The illness of Mr. James C. Pilling, the distinguished specialist, who has for many years had charge of the bibliographical work of the Bureau, has for a time put an end to the publication of bibliographical material. It is fortunate that so much of the important work of Mr. Pilling has already been completed and printed.

The study of the aboriginal languages, which has from the beginning been a most important branch of the work of the Institution, has been carried forward uninterruptedly, and has resulted in a preliminary classification of the Indian tribes. During the year a large amount of new material has been permanently recorded and satisfactory progress has been made in the arrangement of the vocabularies and grammars already collected. The Bureau has in its fireproof vaults several hundred valuable manuscripts pertaining to the Indian languages which are available for the use of students, pending the work of editing and publication. The Bureau has also suffered a severe loss in this department of the work in the death of Rev. J. Owen Dorsey.

In addition to the special branches of investigation already referred to, much has been done in the assembling and classifying of information concerning the Indian tribes.

Satisfactory progress was made in the publication of the results of the Bureau's researches during the year. Eight complete volumes, comprising 10 papers, covering nearly 2,000 pages, with 674 illustrations, were received from press and in part distributed, and other volumes were made ready for the Public Printer.

Further details concerning the operations of the Bureau may be found in the statement of Director Powell, which accompanies this report as Appendix II.

THE SMITHSONIAN INTERNATIONAL EXCHANGE SERVICE.

In making arrangements for the distribution of its early publications the Smithsonian Institution was led to establish relations with foreign scientific societies and libraries, which have proved of very great value in giving effect to one of the principal aims of its founder, "the diffusion of knowledge."

In England and Germany, with which the most active exchange of scientific literature has always been maintained, it has been found necessary to establish special agents, who devote a large part of their time to the Institution's interests.

There thus exists a channel of communication between this and foreign countries by means of which societies or individuals engaged in the promotion of scientific work can exchange publications practically without expense.

The extent of the service is best illustrated, though yet imperfectly, by the accompanying map of the world, which conveys an idea of how the more than 24,000 correspondents of the exchange service are distributed. Upon such a small scale the precise statistical distribution can not, of course, be shown.

The Smithsonian exchange service, which at first was mainly for the distribution of scientific publications, underwent an important change when it became the agency for the United States Government in the exchange of its parliamentary documents for similar documents of foreign Governments, and though Congress now makes annually an appropriation for carrying out the provisions of a treaty formally entered into by our Government to maintain a bureau for "the free transmission of the works exchanged," these appropriations have never been sufficient to meet the entire expense involved, and the service is only kept up by continuing to rely upon the generosity of many of the ocean steamship lines, which in the early days of its existence granted to the Institution the privilege of free transportation in recognition of its disinterested and important scientific work.

The important change to which I refer lies in the fact that so large a proportion[1] of the books carried now consists of Government publications, such, for instance, as the Congressional Record and reports; indeed, in the transmission of such documents alone the Institution has in past years expended of its own private fund over $38,000,[2] for which it has never been reimbursed.

The appropriation for the past year having been restored to its former amount of $17,000, and slightly increased amounts having been made available to certain Government bureaus for the distribution of their

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[1] The exchange of Government documents is about 70 per cent of the entire exchange work.

[2] See Report of the Board of Regents of the Smithsonian Institution, 1890, p. 18.


ALASKA
BRITISH POSSESSIONS
GREENLAND
SOUTH
AMERICA
MAP WORLD
SHOWING THE DISTRIBUTION
INSTITUTIONS INDIVIDUALS
IN REGULAR CORRESPONDENCE
WITH THE
INTERNATIONAL EXCHANGE SERVICE
OF THE
SMITHSONIAN INSTITUTION


SIBERIA
RUSSIAN EMPIRE
RUSSIA
CHINESE EMPIRE
CHINA
AUSTRALIA

reports, it became possible to bring up the arrears of work to which I called especial attention in my last report.

The disbursements on account of the expenses of the exchange office during the year amounted to $21,090.61, of which $16,997.99 were paid from the appropriation of $17,000 by Congress; $4,092.62 were paid by Government bureaus or private institutions, the balance at the close of the fiscal year being held to meet outstanding obligations.

That the exchange service is generously appreciated by its great number of correspondents in this country, libraries, State and private institutions, and individuals, I am well aware, but I am also aware that with the resources at command it is not keeping pace with the growth of the country and the reasonable expectation of its correspondents for the prompt transportation that modern facilities warrant. The improvements that are needed—more foreign agents in the pay of the Institution, more frequent use of rapid transportation, more clerical assistance in properly recording and accounting for packages intrusted to the care of the service—can only be attained by securing from Congress an increased appropriation.

In view of the near approach to completion of the building for the Library of Congress it would seem desirable that steps should be taken to secure a more adequate return from foreign Governments for the large number of publications of the United States sent abroad. How much can be accomplished in this way that cannot be done by correspondence I personally experienced in a visit made during the past year in the interest of this Government exchange to the minister of public instruction in Paris which will, it is hoped, result in securing a very considerable increase in the number of documents received from the French Government.

THE NATIONAL ZOOLOGICAL PARK.

The appropriation made for this purpose for the service of the fiscal year ending June 30, 1895, was in the following terms:

> National Zoological Park: For continuing the construction of roads, walks, bridges, water supply, sewerage, and drainage; and for grading, planting, and otherwise improving the grounds; erecting and repairing buildings and inclosures for animals; and for administrative purposes, care, subsistence, and transportation of animals, including salaries or compensation of all necessary employees, and general incidental expenses not otherwise provided for, fifty thousand dollars; one-half of which sum shall be paid from the revenues of the District of Columbia and the other half from the Treasury of the United States; and hereafter a report in detail of the expenses on account of the National Zoological Park shall be made to Congress at the beginning of each regular session.

The appropriation was not made until August 18, 1894, when the working season was already considerably advanced, and this led to delay and uncertainty in the plans for the year, and owing to this and

the limited amount no change in the character of the development has seemed advisable. It may accordingly be said that the principal aim of the past year has been to keep the animals on hand in proper healthy condition and to improve the general appearance of the park as much as practicable with the limited funds available.

The general agitation of the question of a proper system of streets and roadways in the District of Columbia which has occurred during the last year, owing to the passage of an act authorizing the District Commissioners to establish such a system, has had its effect upon the park in an indirect manner, as it has led to a fuller consideration of the means of access to the park and its probable development in the future.

In the District act of August 7, 1894, the following appropriation was made:

> For opening entrance into Zoological Park, from Woodley Lane road, and opening driveway into Zoological Park, from said entrance along the west bank of Rock Creek, two thousand five hundred dollars, to be paid wholly from the revenues of the District of Columbia.

As this appropriation was associated with others relating solely to District affairs and was payable wholly from District revenues, it seemed proper that the disbursement of the funds should be made by the District Commissioners, who commenced the construction of the roads described in the act.

With the desire that the road might finally come under the control of the park, Mr. H. P. Waggaman, a property owner in that vicinity presented to the park a strip of land, as shown in the plat herewith submitted. (See W.) This addition amounted to 1.217 acres, increasing the total area of the park to 168.70 acres.

The appropriation was wholly insufficient to complete the roadway, and an additional amount was appropriated for the prosecution of this work by the sundry civil act of March 2, 1895, in the following terms:

> For continuing the entrance into the Zoological Park from Woodley Lane, and opening driveway into Zoological Park, from said entrance along the west bank of Rock Creek, five thousand dollars, to be immediately available, which sum is hereby appropriated out of any money in the Treasury not otherwise appropriated, one-half chargeable to the revenues of the District of Columbia.

In accordance with the terms of this appropriation the work on this road was continued, and there is at present a heavy fill completed from the Woodley road down into the park. With the very steep grade at this point it has not been possible to do more than to rough out this road, and it is hardly practicable for carriages. In order to complete it a still greater fill should be made, the road should be macadamized, and a sidewalk constructed. It will then be necessary to construct a bridge across the creek at the point marked A, as the steep cliff on the right side of the creek where the road now ends makes it impracticable

Bird's-eye View of National Zoological Park, from Model.

to carry the road any farther on that bank. Having crossed the creek, the road should continue along the stream on the left bank, traversing the region where the Adams mill formerly stood, and then, as it again reaches a precipitous bank, it should cross on another bridge at or near the point marked B, and communicate with the system of roads now established in the park.

As this road will probably become in time one of the main drives through the park system, it should be well built, have easy grades, and be provided with bridges not only of a substantial character but suitable otherwise to the scenery in which they are to stand, leading as the road does through one of the most beautiful and picturesque valleys in the vicinity of Washington.

Plans for a system of roadways for the District have been completed for that section lying to the eastward of the park. Here a broad street, to be known as the "Park Drive," reaches the boundary of the park at its southeastern corner and thence proceeds along the eastern side by gentle curves adapted to the topography of the region, as shown upon the accompanying plan. The establishment of this road will greatly improve the access to the park, which has always suffered from the steep grades that are necessary for descent into the valley of Rock Creek. It will, however, entail some new difficulties which should be met at once. The road does not skirt the boundary of the park at all points, but touches or leaves it according to the contour of the ground and the practicability of the grade. Some tracts of land are therefore left between the drive and the park, and if these become built upon, a succession of private houses will be thrust directly upon the boundary, marring the air of seclusion that was one of the objects for which the expenditure of the first purchase was made, and which is still a principal attraction of the valley.

In order to avoid this the land in question should be added to the park, the eastern boundary of which would then lie along a broad and excellent roadway affording access to the park at several convenient points. The accompanying map shows the land which should be added. It involves a strip (C) lying immediately south of the bear pits much needed for the security of the animals confined there. At present the boundary of the park is so near the pits that the bank is very steep, and as it is composed in considerable degree of soil and decomposed rock it constantly crumbles under the action of the weather and precipitates loose stones and débris into the pits thus endangering the safety of the animals and gradually undermining the boundary fence, which must sooner or later fall inward. It should also include a tract of land lying on a hillside to the north of the Quarry road and forming a portion of the property of Mr. H. D. Walbridge. This is an exceedingly important tract, as its possession would extend the park toward Kenesaw avenue, which will doubtless be the principal route of access upon the eastern side, and it would be desirable to extend the park on the

southern side by taking in the cemetery that now lies near the Adams mill entrance and constitutes a serious blot upon the surroundings of the park.

The following letter from the landscape architects, Messrs. Olmsted, Olmsted & Eliot, sets forth the advantages of the additions upon the eastern side of the park, and may be considered in connection with the plan just referred to, and the adjoining bird's-eye view, the same letters in each case indicating the same features:

DEAR SIR: We have at various times since our first employment in connection with the Zoological Park strongly urged that more land be acquired in order to secure a suitable boundary at various points.

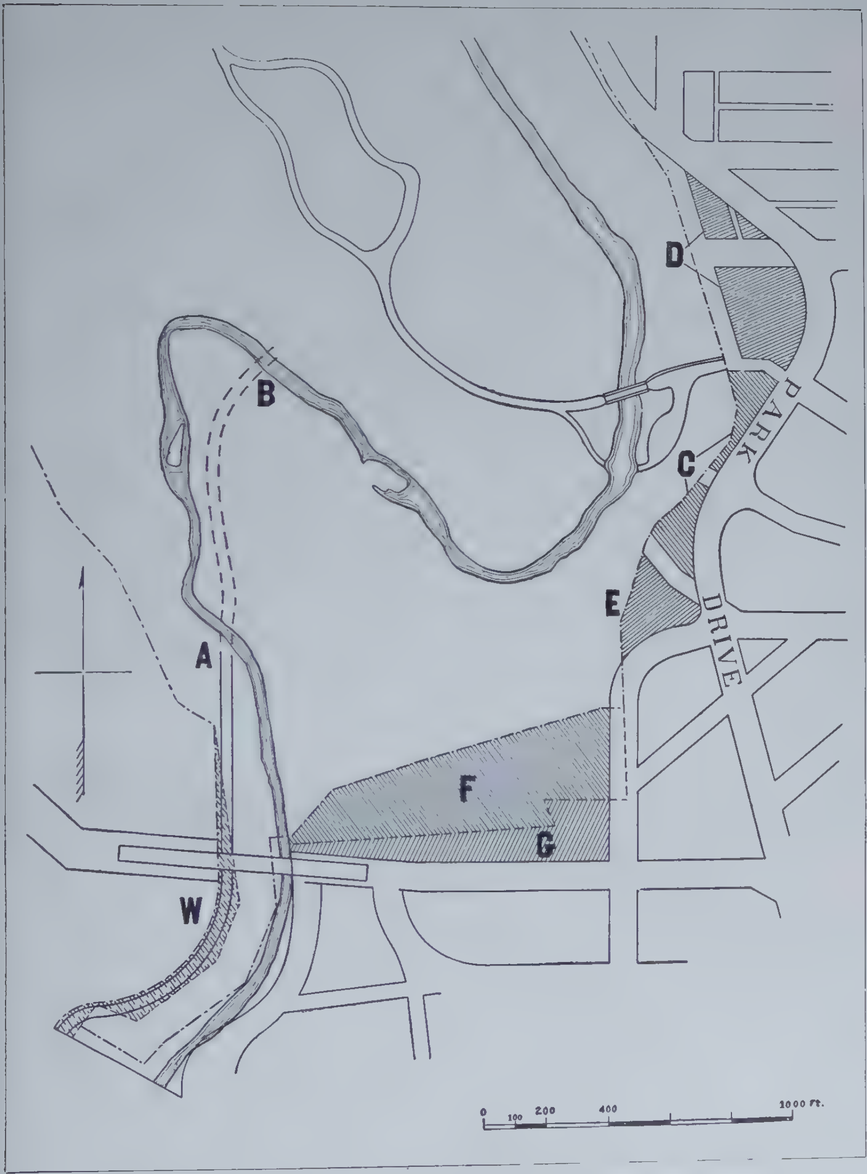
Having been employed a year or more in connection with the plans for the extension of the street system in the city of Washington, we gave considerable study to the question of suitable boundary streets on the east side of the Zoological Park, and in designing these streets we were governed largely by regard for the desirability of adding to the Zoological Park with a view to improving its landscape borders.

It is generally recognized that the Zoological Park is not solely a piece of ground of sufficient area for the proper maintenance and exhibition of living animals, but that it possesses remarkable landscape beauties and includes a considerable part of one of the most characteristic topographical features of Washington, namely, Rock Creek, winding picturesquely among unusually high hills and with beautiful, wooded slopes.

It is obvious, therefore, that in securing land primarily for the purpose of a zoological park it would be a great waste of a most valuable opportunity not to secure also, to be preserved for the enjoyment of the public, the scenery of Rock Creek and the adjoining slopes. This purpose was undoubtedly constantly had in view at the time the Zoological Park was purchased, but unfortunately, owing to the inadequacy of the funds then available, some pieces of land of vital importance in the landscape had to be omitted.

The land which it is of most pressing importance to add as soon as possible to the park lies along the eastern boundary from a point near the southeast corner to Kenyon street. This addition may, if necessary, be secured in three stages.

The most important is a narrow strip (C) above the abandoned quarries now occupied in part as the bear pits, and extending from the end of the southerly branch of Summit road to the Quarry road. Above the solid ledge in the old quarries there is a constantly disintegrating stratum of rock, the face of which is nearly vertical, and from which pieces of rock of considerable size are frequently falling through the action of the weather, endangering people's lives, and also the animals in the cages below and the property of the park. Above this disintegrating rock is a bank of hard earth, approaching the consistency of stone, which stands at an angle much steeper than engineers would regard as safe. This bank can not be sloped back to a gentler inclination, because the top of it ends immediately at the boundary of the park, and it would be a serious damage to the private lands adjoining to have the present surface lowered. We believe that no one examining the matter on the ground would hesitate a moment in acknowledging that an addition to the Zoological Park at this point is a pressing necessity for safety, aside from any consideration of benefit to the landscape and suitability of appearance.



Portion of National Zoological Park, showing adjacent Properties.

The land (D) proposed to be added to the Zoological Park from Quarry road to Kenyon street is of great importance in the landscape from almost all parts of the park. It would be a great misfortune if this land were to be occupied and built upon for private residences. Houses and other constructions on this steep, open hillside, close to the creek and facing toward the most used portions of the Zoological Park, would be excessively conspicuous and destructive of the landscape, which would otherwise have a most unusual degree of continuity and completeness.

The southerly section (E) of the proposed addition to the Zoological Park, extending from the southerly branch of Summit road to a point near the southeast boundary of the Zoological Park, is a very desirable addition to the park, not only for landscape reasons above referred to, but also because if occupied by private residences they would almost necessarily back upon the park, and owing to their high position and the lack of sufficient woods on the steep slopes south of the quarried they would be annoyingly conspicuous from a large part of the park.

One important object to be attained by the whole of the proposes, addition on the easterly side of the Zoological Park is that of securing a frontage upon the new public street recently laid out, and which is from Ontario avenue northward practically an extension of Eighteenth street. The importance of having a public park bound upon public streets instead of against back yards of houses is generally recognized and would alone justify the proposed addition to the park, even if it was not of enormous advantage to the general landscape of the park.

In conclusion, we wish to point out that if the reasons which we have given for the proposed addition are sound ones, and if it is conceded that it should be made very soon because the required land is in a neighborhood which is rising rapidly in value, and which is being rapidly built upon, delay will not only involve additional expense for land and probably much in excess of the interest on its probable present cost, but also there is a strong probability that if the addition is not made at once there will be the cost of new houses and other improvements to be met. * * *

Yours, respectfully,

OLMSTED, OLMSTED & ELIOT.

The amount of land that would be added to the park by these various additions is as follows:

	Acres.
Property of H. D. Walbridge (D)	2.22
Property of Everett Hayden (C)	1.27
Property of Donald McPherson and Mark F. Finley (E)	1.19
Cemetery (F)	5.50
Cliffbourne (G)	2.34

The adjustment of the boundaries of the park and the final establishment of the roads that lead to it will naturally make it necessary to devise a system of roads within the park connecting with the entrance. This can not be fully done until the exterior roads are finally settled, upon the western as well as upon the eastern side. One road has, however, been contemplated, leading from the Adams Mill entrance through the grounds to communicate with the road already adverted to running up the valley from the Woodley Lane road. A small appropriation was set aside for this purpose by the act of March 2, 1895. This will not be available until the beginning of the next fiscal year.

EXTINCTION OF THE BUFFALO.

When the Yellowstone Park was organized it was believed that a permanent place of refuge for the buffalo had been secured, and that out of the natural increase of the hundreds then remaining representative herds would be preserved for future generations. It seems now evident that the conditions in the Yellowstone region are such that the extermination of the Government herd of buffalo may be anticipated, and that it may be accomplished within a very short space of time. The superintendent of the Park appears not to have adequate means for their protection, and there are on the border plenty of persons whose respect for law is insufficient to keep them from poaching when the prize is a buffalo head or skin which will readily sell for several hundreds of dollars. The temptation to these men seems to be irresistible, and as the herd diminishes the value of the animals increases and the difficulty of protection becomes constantly greater.

Since, then, the extermination of the Yellowstone herd seems rapidly approaching, something should at once be done, that this may not mean the extinction of the Government control of the species, with the death of the few specimens now in captivity. Only one course suggests itself as completely efficient—transference of the great part of the now few remaining animals to a region where they can be effectively protected and increase normally under natural conditions, in which case the bison need not vanish from the face of the earth. Two years ago there were supposed to be 200 in the Yellowstone Park. The present estimate is one-quarter of that number. The superintendent reports them as being "*constantly pursued*," and in another year there may be none left. If these animals, or a majority of them, can during the next few months be transferred to the National Zoological Park at Washington, which affords room and security, they will be safe, and their natural increase in the future can be distributed by exchange with the zoological gardens of the various parts of the United States, so that no large city need be without its representatives of the great herds so often referred to in our early history, and now a memory.

Having in mind certain statements made in the public press with regard to the slaughter of the bison within the Yellowstone National Park by marauding poachers, I addressed to Capt. George S. Anderson, U. S. A., the superintendent of that park, a letter of inquiry, to which he made the following reply, which is of interest as supplementing the information given in his annual report to the Secretary of the Interior, and which, though properly belonging to a later report, I give here on account of its urgent importance:

December 12, 1895.

I can give you no definite information about the bison in the Hayden Valley, near your corral. My scouting parties have reported the trails of several small bands leading in that direction, but as the snowfall has been light, they have not as yet been driven to that narrow area.

Buffalo in National Zoological Park.

I do not expect to be able to get an accurate estimate of their number before the latter part of January. I hope there are enough remaining for a source of supply for your park, and if they can be inclosed the cost of maintenance will be very small.

The reports made through the newspapers of the slaughter of the bison recently are, of course, much exaggerated, but unfortunately several have been killed. I feel pretty certain that ten were killed within the past four months. I have now in custody in the guard-house a man who was captured in possession of the scalps of five.

I made a pretty thorough tour of their range in October last, and saw very few signs. I am sure that I have heretofore overestimated their numbers. *I doubt if there are over fifty remaining*, and these will not all winter in the Hayden Valley. They increase but slowly under the best conditions, and here, where they are being *constantly pursued* and where the winters are very severe, but small increase can be looked for. Of course, the stockade recently erected will be a great assistance in their protection, if they can be secured within it.

All of the animals in the park are protected properly and are increasing, *with the exception of the bison*, and of these it is difficult to predict as yet.

There are now but seven of these animals in the National Park here, and even these are a relatively considerable part of the extremely small pure-blooded stock which represents the vanished herds which once covered this continent. An illustration of the head of one of them is given herewith. The present value of such animals being over $1,000, the value of these remaining 50 buffaloes in the Yellowstone is then over $50,000. If so much national property can be saved by the appropriation of one-tenth of that amount, should not this be done on the ground of economy alone; and if, by spending on their transportation little more than the expense of shipping a few carloads of beef cattle, these bison may be saved from extinction, is it not worth while?

The threatened decrease of the collection of animals in the park is a constant source of anxiety. As under the existing appropriations no purchases can be made, recourse is naturally had to the preserves in the Yellowstone Park, from which a number of valuable animals have already been obtained.

The number of persons that avail themselves of the advantages of the park increases year by year, and it seems proper that more adequate provision should be made for the collection than now exists. New buildings suitable for special classes of animals are especially desirable. A suitable elephant house should be built without delay, also an aviary for the accommodation of both native and foreign birds. The property yard, in which are included a blacksmith's and a carpenter's shop, should be removed from the site it now occupies to some less conspicuous location. The following appropriation was made in the District act of August 7, 1894:

For continuing the construction of the Rock Creek intercepting sewer, twenty thousand dollars: *Provided*, That the Commissioners of the District of Columbia are authorized to enter into contract for said work

at a cost not to exceed eighty thousand dollars, to be paid for from time to time as appropriations may be made by law; and the said Commissioners are authorized to construct said sewer, where necessary, across lands belonging to the United States: *Provided*, That after the construction of said sewer the excavated portions of said lands shall be restored to their original condition from the appropriation herein provided for.

In accordance with this law the Commissioners of the District proceeded to survey a course for an intercepting sewer along Rock Creek within the limits of the park. While the engineers in charge of the work have conducted their operations with discretion and courtesy the circumstance has brought forcibly to my attention the desirability of clearly defining the authority of the park officials in cases where it becomes necessary for employees from other branches of the Government to carry on work within the park. There is a very real danger that engineering operations may be conducted so as to injure the animals and destroy the natural beauties of the region, making it impossible to "restore the land to its original condition." As conflict of authority would seriously embarrass the work it would be well if in future cases of this kind the law should specifically provide that operations should be conducted under such reasonable regulations of the park authorities as may insure, as far as practicable, the safety of the animals and the preservation of the natural features of the park.

Immediately subsequent to the date of this report one of the most interesting and valuable animals of the park (a sea lioness) died from fright, due to an explosion without warning caused in the progress of the work just referred to.

ASTRO-PHYSICAL OBSERVATORY.

The investigation of the infra-red spectrum has been continued in the Astro-physical Observatory during the past year with increased energy, and I am glad to be able to say that if only provisional results have yet been published, which, like those of last year's report, are intended merely to show the character and progress of the work, it is because the means of giving greater exactness are constantly growing, so that the result it is now hoped to present will be given with the aim of a still higher standard of precision; an aim which it may be trusted will be considered a legitimate cause for the delay in the appearance of the final results.

I refer for all details to the more extended report given later, but, briefly, it may be stated that a larger number of bolographic records has been obtained than in any previous year, and that these continuous observations have been accompanied by further improvement in the apparatus, a higher standard of accuracy, and a nearer approach to the completion of the research; but that they have also shown beyond a doubt that the limit of accuracy which is desirable can never be

reached in the present most unsuitable, provisional site, which is subject to every kind of disturbance due to the neighborhood of the streets of a busy city.

NECROLOGY.

I am called upon to record here the death of two Regents of the Institution, Dr. James C. Welling and Dr. Henry Coppée; also three gentlemen long associated with the work of the Institution, Mr. William B. Taylor, Col. Garrick Mallery, and Rev. James Owen Dorsey, besides Mr. Robert Stanton Avery, who has bequeathed his estate to the Institution.

JAMES CLARK WELLING.

I have lost in Dr. Welling a personal friend, but I only have to speak of him now in his relationship to this Institution—an institution whose character has been partly due to its good fortune in the presence and advice of such men.

Dr. Welling was one who possessed, beyond anyone else, what may be called the traditions of the Institution; and though these were not of course his exclusive property, in this respect, as in others, his loss can not be supplied.

The rules of conduct which have been laid down by the Regents, and by the Secretaries who have administered them, are not so much derived from *a priori* views as they are the outgrowth of accumulated experience; and this experience, it has been thought, is in part, due to the exceptionally long incumbencies of members of the Board as compared with ordinary tenures of office here, and to the continuity of the knowledge of its activities, as illustrated in the case of this departed friend.

James Clark Welling, at the time of his death, September 4, 1894, was nearly 70 years of age.[1] Descended from New England colonial ancestors, a native of one of the Middle States, in early manhood a teacher in the South, and for nearly half a century a resident of the national capital, he was an American of the best type, free from sectional bias, personifying the higher traits and tendencies of the nation, loyal to the traditions and aspirations of its founders.

He was graduated in 1844 from the College of New Jersey, studied law, and was admitted to the bar, but soon afterwards entered upon the profession of journalism. He always retained, however, a strong inclination for the study of constitutional and international law, and of politics, and his interest in public affairs was greatly stimulated by his connection for fifteen years with the most important of Washington journals, at that time national in its influence. He became the literary editor of the National Intelligencer in 1850, and was its managing

[1] He was born in Trenton, July 14, 1825.

editor throughout the entire period of the civil war. In this capacity he had the privilege of personal acquaintance with all our public men, and confidential access to many of them, including Lincoln, Seward, and Stanton.

In later life his attention was given chiefly to educational work. For a time president of St. John's College, Maryland, and later professor of belles lettres at Princeton, he was, in 1870, recalled to Washington to become president of the Columbian University, an institution founded fifty years before, in the hope that it might fulfill the desire of Washington, Barlow, and Adams, that a seat of liberal learning should exist at the capital. Dr. Welling was led to accept this position by the urgency of the philanthropist Corcoran and the advice of Henry, both of whom were influenced by the hope of having with them one of the founders of a national university, and who believed that a man of Dr. Welling's character would find in such a position a wide field of influence.

His aspirations for the university were never fully realized, owing to the impossibility of securing endowments from private sources for a public institution located so near to the seat of Government. He nevertheless secured a considerable addition to its endowment, added new professional schools, greatly increased the number of its faculty and students, removed the institution from the suburbs to a new building in the heart of the city, and accomplished many other things which seemed really wonderful in view of the smallness of the resources at his command. The dream of his life was to establish a school of comparative jurisprudence—the only one of its kind in the world—as a branch of the university. In 1892 he visited Europe, secured approval of his plans from Sir Frederick Pollock and other eminent jurists, and their promise to come to America to lecture as members of the faculty. Failing health interfered with the realization of his plan, which, I can but believe, he would have otherwise forced into success.

After his resignation of the presidency in 1893, he still retained the chair of international law and the position of dean of the university law school, and, full of hopefulness, it was his purpose to labor on for his beloved project. He confidently expected to live to be 80, and to devote the remaining ten years of his life to the compilation of a political history of the civil war, a work for which no one was so well qualified by experience, knowledge, and critical skill as himself. He was a representative man in Washington, identified with all interests which tend toward good citizenship, and held many positions of public trust and honor. He was president of the board of trustees of the Corcoran Art Gallery and of the American Copyright League, and was appointed by President Harrison commissioner to the Columbian Historical Exposition at Madrid in 1892. His scholarship was accurate, broad, and genial, as was shown by the critical reviews which he contributed during his later years to some of the principal American journals. His

favorite study in hours of relaxation was that of the sacred poetry of the early Christian Church, some of which he had translated, though not for publication.

In 1884 he was chosen a Regent of this Institution, to succeed the Reverend Dr. Parker. For ten years he gave conscientious attention to its interests, and upheld in every way those conservative and dignified traditions of which I have already spoken of him as almost the living embodiment; and while he did this primarily because of their harmony with his own personal tendencies and convictions as to their value, he did so because of his affection and reverence for the first Secretary, Joseph Henry, whose pupil he had been in his youth, and with whom in middle life he maintained the relation of friend and confident. After Henry's death, Dr. Welling consented to add to his already burdensome duties those of the chairman of the executive committee, which he performed till his own death, so that he may be said to have been a link between the past and present in the history of this Institution, though happily not the only one, since it has preserved others in his contemporaries.

At a meeting of the Board of Regents in January, 1895, the following resolutions were adopted:

Whereas the members of the Board of Regents of the Smithsonian Institution have been called upon to mourn the death of their esteemed colleague, the late James C. Welling, LL. D., president of Columbian University, who has long been interested in the welfare of the Institution, and who for many years has been a Regent and chairman of its executive committee,

Resolved, That the Board of Regents feel deep regret in the loss of one whose long and distinguished career of public usefulness, especially in the promotion of institutions for higher education, commanded their respect, and whose personal character and unselfish devotion to the highest ideals of scholarship and citizenship, their sincere admiration.

Resolved, That in the death of President Welling the Smithsonian Institution has suffered the irreparable loss of an earnest friend, a wise and judicious counselor, and one who was preeminently an exponent of its time-honored policy, and the Board of Regents a friend and associate whom they valued most highly.

Resolved, That these resolutions be recorded in the journal of the proceedings of the Board, and that the secretary be requested to send a copy of them to the family of their departed associate and friend, in token of sympathy in this common affliction.

HENRY COPPÉE.

Henry Coppée, LL. D., a member of the executive committee of the Board of Regents of the Institution, died March 21, 1895, in his seventy-fourth year. He was appointed Regent January 19, 1874, was reappointed by Congress every six years, and during that score of years constantly took the deepest interest in the work of the Institution.

Dr. Coppée was born in Savannah, Ga., October 13, 1821, and was of French ancestry.

After spending two years in the class of 1839 at Yale, he left college to study practical civil engineering, being engaged in the construction of the Georgia Central Railroad. July 1, 1840, he entered the United States Military Academy at West Point, from which place he was graduated four years later, being promoted to second lieutenant of artillery July 1, 1845. The following year, after having served in garrison, and at Fort Columbus, N. Y., he was sent to Mexico, taking part in the battles of Vera Cruz, Cerro Gordo, Cherubusco, and Contreras in 1847, being then promoted to the rank of first lieutenant and breveted captain for "gallant and meritorious conduct" in those battles.

Dr. Coppée was assistant professor of French at West Point Academy from August 22, 1848, to June 22, 1849, and after spending a year at Fort McHenry, Md., he returned to West Point and remained there five years as assistant professor of English studies. On June 30, 1855, he resigned from the Army, and for eleven years was professor of English literature at the University of Pennsylvania, when in 1866 he was elected the first president of Lehigh University. His love for literary rather than administrative labor induced him to resign the presidency of the university in 1875, and to accept the chair of English literature, international and constitutional law, and the philosophy of history. Upon the death of President Lamberton in 1893 he again became head of the university, and was acting president when he died.

He was an industrious author, his published works covering a wide range of subjects, though pertaining chiefly to history and English literature.

His genial courtesy and manly disposition, the prudent counsel of his disciplined and well-stored mind, and his devotion to the interests of the Institution will linger in the memory of his colleagues on the Board of Regents. As a soldier, as man of letters, as professor and president of a great university, Dr. Coppée won high distinction, and died leaving a record of well spent years.

ROBERT STANTON AVERY.

Robert Stanton Avery, of Washington City, was born near Preston, Conn., May 1, 1808, and died in Washington on September 12, 1894. He early became interested in mathematics and physical science and in Latin and Greek, and for several years was engaged in teaching school in various parts of Connecticut and Massachusetts, and also in Ohio and Kentucky. Actuated by a desire for higher education he entered Harvard College at the age of 35 and there devoted much of his time to a critical study of the Scriptures in Greek and Hebrew. After his graduation in 1846 he obtained a license as a preacher, but failing health prevented active work in that profession.

From 1853 to 1885 he was connected with the United States Coast Survey, his principal work being computation and reduction of tidal observations.

After resigning from the Government service he prepared for the press a set of mathematical tables, also some schoolbooks designed for the teaching of phonetic spelling, a subject in which he became much interested, and in establishing "The Avery fund" of the Smithsonian Institution he expressed a wish that the income be used chiefly for publications relating to the mechanical laws governing an etherial medium and also mathematical tables and works on phonetic type and writing.

WILLIAM BOWER TAYLOR.

William Bower Taylor, who died February 25, 1895, was appointed assistant and editor in the Smithsonian Institution in 1878. He was born in Philadelphia May 23, 1821; graduated at the University of Pennsylvania in 1840; studied law and was admitted to the bar November 15, 1843. In 1853 he came to Washington as draftsman and foreman of the engineer and machinist departments at the United States navy-yard, and in 1854 was appointed principal examiner, and later librarian, in the United States Patent Office. He was one of the founders and the fourth president of the Washington Philosophical Society, and was a member of the American Philosophical Society, the American Association for the Advancement of Science, and of other learned bodies. He represented the Smithsonian Institution at the International Electrical Exhibition in Philadelphia in 1884. Among his literary works may be mentioned the Life and Writings of Prof. Joseph Henry; Professor Henry and the Telegraph, and papers on Gravitation, Force, and Sound, published by the Institution.

Necrologic notices of Col. Garrick Mallery and James Owen Dorsey, for many years connected with the Bureau of Ethnology, are given by the Director of the Bureau in an appendix to this report.

Respectfully submitted.

S. P. LANGLEY,
Secretary of the Smithsonian Institution.

APPENDIX TO SECRETARY'S REPORT.

APPENDIX I.

THE NATIONAL MUSEUM.

SIR: I have the honor to present a brief statement of some of the most important features connected with the operations of the National Museum during the fiscal year which ended on June 30, 1895.

Accessions.—During the year the collections have been increased by 1,223 accessions, numbering about 127,000 specimens. This compares favorably with the last four years. The large increase is almost entirely the result of a warm interest in the welfare of the Museum on the part of individuals, many of whom have at one time or another received some courtesy from the Museum, either in the way of a publication or special information on some scientific subject. Collections of more than ordinary interest have been contributed by Dr. William L. Abbott, Mr. William Astor Chanler, and Lieut. von Höhnel, His Majesty the King of Siam, the Reverend L. T. Chamberlain, Mr. A. Boucard, Dr. William L. Ralph, and others. Important gifts have also been received from the Indian Museum in Calcutta and from the Government of Nicaragua.

The scientific staff.—During the year all the collections of fossils have been placed under one curator, and are now administered under the department of paleontology, of which Hon. C. D. Walcott, Director of the U. S. Geological Survey, is the honorary curator. The vertebrate fossils are in charge of Prof. O. C. Marsh and Mr. F. A. Lucas. Among the invertebrate fossils, the Paleozoic collection is under the care of Mr. Charles Schuchert. The Mesozoic fossils are administered by Mr. T. W. Stanton, and the Cenozoic, or Tertiary, fossils by Dr. W. H. Dall. The collection of fossil plants is under the charge of Prof. Lester F. Ward, with Mr. F. H. Knowlton as custodian of the Mesozoic plants and Mr. David White as custodian of the Paleozoic plants.

Mr. J. E. Watkins has been appointed curator of all the technological collections. Dr. J. M. Flint, of the United States Navy, has been again detailed by the Secretary of the Navy to serve as honorary curator of the section of materia medica, in place of Medical Inspector Daniel McMurtrie. Dr. J. N. Rose, of the Department of Agriculture, has been appointed honorary assistant curator of the department of plants. Dr. Walter Hough, Mr. C. W. Richmond, and Miss M. J. Rathbun, have been designated assistant curators in the departments of ethnology, birds, and marine invertebrates, respectively. Mr. F. H. Cushing, of the Bureau of Ethnology, has been designated custodian of the Pueblo collections.

Distribution of collections.—There have been 39,236 duplicate specimens distributed during the past year to universities, colleges, museums, and, in a few special instances, to normal schools. This shows an increase of about 13,000 specimens over the distributions of last year. The material distributed consisted principally of rocks and ores, invertebrate forms of marine life, fishes, casts of prehistoric implements, and minerals. More than half the total number consisted of marine invertebrates. Large quantities of marine forms are collected by the U. S. Fish Commission, and as soon as

practicable after the material has been studied and transferred to the Museum, selections are carefully made with a view to the preparation of "sets" for distribution. It is quite impossible, however, to fill more than a small proportion of the applications received, until Congress makes a special appropriation to be used for the employment of experts in separating the duplicates in the various departments of the Museum and arranging them into collections especially suited for use in educational work.

Visitors.—There has been an increase of nearly 8,000 in the number of visitors to the Smithsonian and Museum buildings during the year. The total for the Smithsonian building was 105,658, and for the Museum building 201,744.

Specimens transmitted for identification.—During the year 467 "lots" of specimens were forwarded to the Museum for examination. Only a very small proportion proved desirable for permanent addition to the collections. If the specimens sent have any value, their return is almost invariably requested. If, however, the Museum is permitted to retain desirable specimens, they are recorded in the Museum catalogues, first as received for examination and report, and again as gifts to the Museum. It is rarely the case that specimens thus retained have any intrinsic worth, their value usually consisting in the fact that they fill gaps in certain series. During the past year the services of the curators in examining and reporting upon material were extended, outside of the United States, to correspondents in Canada, Great Britain, Central America, South America, Mexico, Australia, New Zealand, India, Java, Borneo, Philippine Islands, several countries of Europe, and various islands in the Pacific Ocean.

Foreign exchanges.—Exchanges have been made with several foreign museums during the year. Among them are the Royal Museum of Northern Antiquities, Copenhagen, Denmark; Indian Museum, Calcutta, India; Canterbury Museum, Christchurch, New Zealand; Museum of Natural History, Paris, France; Manchester Museum, Manchester, England; Museum of Natural History, Vienna, Austria; La Plata Museum, Buenos Ayres, Argentina, and others. Important exchanges have often been effected with individuals, such as Dr. A. C. Haddon, Cambridge, England; Mr. Edgar J. Bradley, Happy Valley Water Works, South Australia; Dr. H. von Ihering, San Paulo, Brazil; Mr. M. Stossich, Triest, Austria; Prof. Edward Tregear, of Wellington, New Zealand.

Publications.—The report of the Museum for 1892 has been published during the year, and the report for 1893 is now going through the press. The papers (976–1032) constituting volume 17 of the Proceedings of the National Museum have, with one exception, been distributed, and the edition of the bound volume is expected daily. Advance sheets of two papers containing descriptions of new species, and intended for inclusion in volume 18, were issued during the year in order to secure to the authors priority of description.

Of the Bulletin, No. 48, "Contribution toward a Monograph of the Insects of the Lepidopterous Family Noctuidæ of Boreal North America, A Revision of the Deltoid Moths," by John B. Smith, Sc. D., has been published. The following "Parts" of No. 39 are now in the folding room: Part H, "Directions for collecting Minerals," by Wirt Tassin; Part I, "Directions for collecting Rocks and for the preparation of Thin Sections," by George P. Merrill; Part J, "Directions for collecting specimens and information illustrating the Aboriginal Uses of Plants," by Frederick V. Coville; Part K, "Directions for collecting and preparing Fossils," by Charles Schuchert. A supplemental edition of Part A, "Directions for collecting Birds," by Robert Ridgway, has been printed at the expense of the Museum allotment, in order to supply the extraordinary demand for this publication.

The second of the series of Special Bulletins, in quarto form, entitled "Oceanic Ichthyology," relating to the deep sea and pelagic fishes of the world, by G. Brown Goode and Tarleton H. Bean, has been set in type and will probably be published during the winter. The third number of the series, being the second volume of Life Histories of North American Birds, by Maj. Charles Bendire, is for the most part in type. It will be illustrated with seven chromo-lithographic plates.

Circulars 43 to 46 have been published. Nos. 43 to 45 have reference to the development of the library of the National Museum, and request the transmission of the publications of scientific establishments as well as authors' separates or reprints. No. 46 invites the cooperation of students and collectors in forwarding plants found in the District of Columbia, and making notes concerning them, for incorporation in a proposed revised edition of Bulletin 22, by Prof. Lester F. Ward, entitled A Guide to the Flora of Washington and Vicinity. This was published in 1881.

Explorations.—The Museum has benefited during the year by the results of the explorations of Dr. William L. Abbott, who has forwarded valuable ethnological and natural history material from Africa and India.

Mr. William Astor Chanler has continued his travels in Africa, and has made important contributions to the collections.

Prof. William Trelease, Director of the Missouri Botanical Garden, St. Louis, gathered a number of interesting specimens of natural history, including marine invertebrate forms, reptiles, fishes, birds, and insects, in connection with his expedition to the Azores.

Large collections of mammals and pottery have resulted from the explorations of Lieut. Wirt Robinson, U. S. A., in Florida.

Mr. Mark B. Kerr made a very acceptable collection of fossils in Ecuador, which he presented to the Museum.

Cotton States and International Exposition, Atlanta.—The exhibit prepared under the auspices of the Smithsonian Institution for display at the Cotton States Exposition illustrates every phase of the activities of the Institution and its branches, especially the National Museum. The exhibits of the latter include collections prepared by the departments of mammals, birds, reptiles, fishes, comparative anatomy, marine invertebrates, mollusks, insects, paleontology, geology, minerals, botany, prehistoric anthropology, ethnology, and some of the sections of the department of arts and industries, i. e., materia medica, oriental antiquities and religious ceremonial, some technological exhibits, and a collection of games. The space assigned to the Institution includes 5,300 feet of floor space, exclusive of the central aisle, and is located in the southeastern quarter of the Government building. The sum allotted to the Smithsonian Institution and the National Museum was $22,000. Of this amount $16,500 was made available for expenditures connected with the preparation of the exhibits, the remainder being intended to cover the expenses of installation. The Exposition opens on September 18 and closes on December 31. The report of the National Museum for 18 6 will contain a complete description of these exhibits and a full account of the participation of the Smithsonian Institution and its various branches.

Respectfully submitted.

G. BROWN GOODE,

Assistant Secretary in charge of the U. S. National Museum.

Mr. S. P. LANGLEY,

Secretary of the Smithsonian Institution.

JUNE 30, 1895.

Appendix II.

REPORT OF THE DIRECTOR OF THE BUREAU OF AMERICAN ETHNOLOGY FOR THE YEAR ENDING JUNE 30, 1895.

Sir: Ethnologic researches have been prosecuted during the fiscal year in accordance with act of Congress making provision "for continuing researches relating to the American Indians, under the direction of the Smithsonian Institution." The operations have been conducted in accordance with the plan submitted at the beginning of the fiscal year, with minor modifications made necessary by circumstances.

The primary classification of the work is topical, and the researches along different lines comprise field studies or exploration and office work in the elaboration of the material collected in the field or obtained in other ways. The chief researches during the last year relate to (1) archeology, (2) descriptive ethnology, (3) sociology, (4) sign language and hieroglyphics, (5) linguistics, (6) mythology, (7) psychology, (8) bibliography, and (9) publication, together with administrative and miscellaneous work.

In the usual course the researches begin in the field, where surveys are made and where information and material are collected. The data obtained in this way are studied and compared and reports thereon are written in the office, and the reports thus prepared are, after examination by the Director or by the ethnologist in charge under his instructions, transmitted for publication. The scientific operations therefore include (1) fieldwork or exploration, (2) office researches, including the preparation of reports, and (3) publication.

EXPLORATION.

During the earlier portion of the fiscal year Mr. Cosmos Mindeleff was occupied in extending and completing his explorations and surveys in southwestern United States. During the field season of 1894 his operations were largely confined to Canyon de Chelly in northeastern Arizona, but his reconnoissances and surveys were extended into contiguous territory. During July and the earlier part of August he examined San Juan Valley and there obtained information of much interest. In its topography and general geographic conditions this region appears to have been well adapted to the needs of the ancient pueblo builders, and it affords examples of nearly all the types of aboriginal villages now known, together with other types and many variants which have not been surveyed elsewhere. The examination and comparative study of these relics throw much light on the development of art in architecture by the people of the pueblos. In other directions, too, the observations add materially to knowledge of the habits and customs of the aborigines. Mr. Mindeleff's researches during the season, in connection with his surveys during the last fiscal year, have covered a large territory and will permit archeologic mapping of value; even the negative results are useful as indicating the territory barren of aboriginal works.

Early in September Mr. Mindeleff brought his field operations to a close. The greater part of the month was spent in completing his accounts and disposing of his field outfit and equipment. Toward the end of the month he repaired to Washington to begin the preparation of a final report on his surveys of the preceding fifteen months.

The most extended exploratory work of the year was that of an expedition through the country of the Papago and Seri Indians of Arizona and Sonora (Mexico), conducted by Mr. McGee. The expedition was fitted out in Tucson about the middle of October. Mr. William Dinwiddie accompanied the expedition as photographer, and the party included also a Papago Indian interpreter and from time to time Indian or Mexican guides and interpreters. Leaving Tucson, the party proceeded to and through San Luis Valley and temporarily crossed the frontier at Sasabe to the Papago Indian village of Poso Verde. Here the leader and interpreter remained several days, collecting information concerning the distribution of the Papago villages and rancherias, while Mr. Dinwiddie was sent back to Tucson to make necessary changes in outfit. A few days later the party reassembled at Arivaca, Ariz., where surveys were made of extended prehistoric works. Thence the expedition moved to the frontier at Nogales, where after some delay authority for extending the operations on Mexican soil was courteously accorded, in response to representations made through the local officials to the federal officers of the Republic of Mexico. Leaving Nogales, the party proceeded southward, visiting several villages formerly occupied by Papago Indians but now abandoned, and finding rancherias occupied by representatives of the tribe at various points.

The rancherias near Querobabi were found especially interesting, and a number of valuable photographs were taken. While a primary purpose of the expedition was the collection of objective material for preservation in the United States National Museum, little such material was collected during this part of the trip, (1) because of the desire to comply with the spirit of the Mexican law relating to the removal of antiquities, and (2) because of the difficulty of transporting objects over many hundred miles of frequently trackless territory. Other Papago rancherias were found as far southward as Hermosillo, and information was obtained concerning settlements midway between that city and Guaymas. During the journey from Tucson to Hermosillo the eastern and southern limits of the Papago territory were determined, many of the characteristics of the tribe were ascertained, and their arts were studied in such manner as to facilitate subsequent collection of typical objects.

After two or three days' delay in Hermosillo, due to the difficulty of obtaining authority to enter the territory of the warlike Seri Indians, the expedition proceeded toward the coast adjacent to Tiburon Island. During this part of the trip the expedition had the pleasure and advantage of the company of Señor Pascual Encinas, an aged Mexican, formerly of great energy and courage, who had done much to extend white settlement into the Seri country, and whose services in this direction have received abundant recognition on the part of the State and the Republic. Piloted by Señor Encinas and Señor Alvemar-Leon, the expedition entered the borders of the Seri territory and was so fortunate as to find a temporary rancheria occupied by some sixty individuals of the tribe. During the ensuing week their habits and customs were studied, a part of their vocabulary was recorded, and a number of individual and group photographs were made. In addition typical articles of costumery, weapons, utensils, etc., were collected and some information was gained concerning the ethnic characteristics of the tribe. The Indians were found quite primitive, probably more primitive and savage than any other tribe remaining on the North American continent. Most of their food is eaten raw, they have no domestic animals save dogs, they are totally without agriculture, and their industrial arts are few and rude. By reason of their warlike character, little has hitherto been known concerning the tribe; the photographs made by the expedition are the first known to have been made of the Seri Indians.

Returning to Hermosillo early in November, the party set out on the return journey, so shaping the course as to determine the southwestern limits of Papago occupancy. Interesting Papago rancherias were found at Poso Noriago and at Cienega, and in both localities photographs and a few small objects of special interest were obtained. Between these points several prehistoric ruins were dis-

vocered, and also examples of the singular prehistoric works called by the Mexicans "las trincheras" (entrenched mountains) observed. Passing northward, the ancient Papago town of Caborca was visited and additional photographs were made. A remarkable example of entrenched mountain near this point received careful attention. From Caborca the expedition proceeded to Pitiquita, where opportunity was again presented for collecting Papago material, and thence to Altar. The limit of the time fixed for the journey on leaving Tucson being nearly at hand, and the stock having suffered greatly from the rigors of travel through one of the most arid of regions, it was found necessary here to abandon the plan for extending the studies to San Domingo and Quitobaquita, the westernmost settlements of the Papago; and the expedition proceeded directly toward the boundary near Sierra de la Union, between Rancho de San Joaquin, in Sonora, and Rancho Ventano, in Arizona.

There are several Papago rancherias near the last-named rancho, and in these collections and photographs were made. The party then proceeded to Fresnal, the principal Indian village in Papagueria, where the team was loaded with objects obtained from the Indians. Later, Tucson (Indian) was visited, and afterwards a stop was made at the Papago village of Coyote. Between the last-named points and at Coyote prehistoric villages and other antiquities of much interest were noted, and a small collection of fragmentary prehistoric pottery, etc., was made. On November 25 the expedition returned to Tucson, and immediately on disbanding the ethnologist in charge repaired to Washington, Mr. Dinwiddie remaining for a few days for the purpose of completing collections on the Papago Reservation at San Xavier. The expedition resulted in a considerable collection representing the arts and industries of the partially acculturized Papago Indians, whose arts have been hitherto but meagerly represented in the National Museum or other repositories of scientific material; in the first noteworthy collection of objective material ever made among the Seri Indians; in some 500 photographs of the Seri and Papago Indians and their surroundings, this collection being of special interest since the Seri Indians have not hitherto been photographed, while few pictures of the Papago have hitherto been taken; and in a considerable body of ethnic material appertaining to both tribes.

Toward the close of the calendar year Dr. Franz Boas, who had visited British Columbia for the purpose of continuing researches relating to the native languages under the auspices of the British Association for the Advancement of Science, communicated with the Bureau, suggesting that he be given authority and means for visiting the Kathlamet Indians of the lower Columbia region and collecting texts representing their language and mythology. After correspondence he was authorized to carry out his plan of operations, the material collected to be conveyed to the Bureau for a stipulated sum. Dr. Boas devoted several weeks to the work, and after his return to eastern United States prepared the material for publication. It was not quite complete at the end of the fiscal year, but was soon afterward transmitted and found to be a valuable addition to knowledge concerning the northwestern tribes.

About the end of December Mr. James Mooney proceeded to the field in Indian Territory for the purpose of making researches concerning the Kiowa calendar and the Kiowa heraldic system. He remained dwelling among the Kiowa Indians until after the close of the fiscal year. Among the Kiowa as among other Plains Indians, and indeed among all of the aboriginal tribes, there is a widespread symbolism by which the arts are influenced and guided. Under this symbolism tents, shields, arrows, pipes, musical instruments, robes, and other articles are inscribed, painted, or otherwise marked with designs. In many cases these designs possess decorative value, and by superficial students they are commonly supposed to be used simply for decoration; but study of the Indian character and motive shows that the design is not primarily decorative (though the germ of decoration may be found therein), but symbolic and fraught with meaning to those who understand the symbolism. This primitive symbolism is found to be developed and differentiated in various

ways among different tribes of the American aborigines; among the Kiowa Indians it is differentiated into a crude yet highly significant system of heraldry which throws much light on the medieval heraldry of Europe; and in another direction it is differentiated into a system of winter counts or calendars, forming at the same time a chronologic system and an historical record which, although crude and imperfect, are of great interest. Among the same Indians the system of symbolism has been differentiated in a third direction, though one nearly parallel with the first, in such manner as to form a symbolic record of social organization and relation, this part of the record being largely painted on the dressed-skin tents. Thus the symbolism of the Kiowa Indians elucidates the origin of several arts brought to perfection only among much more highly cultivated people; it represents a crude heraldry, a budding cronology, a nascent decorative art, and the germ of writing.

Although remaining in the field, Mr. Mooney made considerable progress during the fiscal year in the preparation of a memoir on the Kiowa calendar, though the manuscript will require revision as his studies approach maturity, after his return to the office.

Office Work.

ARCHEOLOGY.

Prof. W. H. Holmes, who retired from the Bureau before the beginning of the fiscal year, left two reports nearly ready for publication; one of these relates to the stone art of the aborigines as exemplified and elucidated by the relics found in and near the tide-water region adjacent to Chesapeake Bay; the second to the fictile art as represented by collections from eastern United States, especially from the mounds. While both reports were substantially complete as to letterpress, they were incomplete as to illustrations, and the preparation of requisite illustrations was carried forward under the supervision of the ethnologist in charge and Mr. DeLancey W. Gill. During July a number of photographs were made, for incorporation in the memoir on stone art, by Mr. Cushing and Mr. William Dinwiddie. When the illustrations were completed the memoir was incorporated in the Fifteenth Annual Report of the Bureau, which was sent to press during the year.

During portions of July and August Mr. Dinwiddie was engaged in the elaboration of notes on a remarkable steatite quarry near Clifton, Va., and in the transfer of the collections to the National Museum. The Clifton quarry is one of the largest of the aboriginal excavations of soapstone thus far found in eastern United States, and is noteworthy for the depth of the cutting and the large amount of fragmentary and other material representing the processes of primitive quarrymen. Mr. Dinwiddie's work on this material was interrupted when he joined the expedition into the Papago country, and his report has not been completed.

Mr. Cosmos Mindeleff, who returned from the field about the end of September, was occupied during the greater part of October in closing his accounts and in other duties connected with the termination of long continued field operations. Afterwards he began the preparation of a report on his surveys and researches. During November, December, and January the material was reduced to the form of a memoir on the cliff ruins of Canyon de Chelly. In February a preliminary draft of the text was brought to substantial completion, and the later portion of March was spent chiefly in the preparation of illustrations. During March and April the text was revised and rewritten, and toward the end of the latter month it was submitted for publication. The preparation of the final drawings for the illustrations was also substantially completed, and in June the memoir was assigned for publication in the Sixteenth Annual Report of the Bureau.

Mr. Mindeleff's surveys recorded in his report on Canyon de Chelly were both extended and detailed, and have yielded a large body of especially trustworthy data relating to this interesting portion of the continent. In a large number of cases he made diagrams showing the ground plans of structure, based on careful measure-

ments, and these plans were connected in plats which were in turn combined into maps. Whenever practicable the plans were supplemented by drawings in elevation and perspective, and by photographs; and the photographic and other illustrations present vividly the characteristics of the region examined and the conditions under which the ancient cliff dwellers lived, moved, worshiped their mysteries, defended themselves against enemies, died, and were buried Many explorations have been made in the Southwestern region, and many students have collected material relating to the peculiarly intelligent aborigines of this district; but none of the explorations have been more thorough, none of the records more faithful, than that just completed by Cosmos Mindeleff, and it is thought that his report will make Canyon de Chelly classic ground for the archeologist.

Although conducted primarily for other purposes, the expedition directed by Mr. McGee resulted in a number of interesting archæologic discoveries. Among these may be mentioned: (1) "Las Trincheras," a class of temporary fortifications about isolated buttes or peaks near habitable valleys, forming a new archæologic type for this country; (2) a considerable number of prehistoric village sites, irrigation works, etc., in a region heretofore supposed to be barren archæologically; (3) extended village sites, each dominated by one or more ceremonial or other ground structures, sometimes accompanied by inclosures suggesting the domestication of animals; and (4) great acequias, carried farther up the valley sides than the present irrigation works, indicating more complete conquest of the waters during prehistoric times than at present. The archæologic material collected during the expedition has not been prepared for extended publication, but is withheld for further research in the same region.

Although the collections in the National Museum made by members of the Bureau in former years for the purpose of illustrating the life of the Pueblo tribes since the Spanish advent is exceedingly rich, comparatively few objects representative of the prehistoric arts of these interesting people have been collected. Opportunity having at last been afforded for excavation among the remains of the ancient cliff-dwellings and pueblo peoples of the Southwest, the Bureau was fortunate enough to enlist the services of the late director of the Hemenway Expedition, Dr. J. Walter Fewkes, the results of whose researches among the Hopi Indians of Tusayan, Ariz., are well known. Dr. Fewkes proceeded, late in May, to the unfrequented locality known as the Red Rock country, southwest of Flagstaff, Ariz., where he had the good fortune to find a group of extensive cliff ruins hitherto unknown to archæologists and not despoiled by white men. Excavation was prosecuted among these aboriginal remains during June with considerable success, and a number of excellent photographs were made. At the end of the month Dr. Fewkes returned to Flagstaff with a view of reoutfitting for a thorough exploration of some of the extensive and presumably rich ruins in the Tusayan country of northeastern part of the territory.

DESCRIPTIVE ETHNOLOGY.

Ever since the discovery of the American continent explorers have been impressed by the characteristics of the aborigines, and many of them have recorded their observations and impressions in reports, letters, diaries, and treatises, and great numbers of these records have been printed and published to the world. In this way a great body of literature, sometimes styled Americana, has been produced. A great part of this body of literature relates partly or wholly to the American Indians. Usually the records were based on superficial observation and frequently they are vitiated by misapprehension and hasty generalization. Nevertheless much of the literature represents actual observation of the Indians while yet they retained primitive characteristics. Thus, although the early records are diverse in value, the body of the literature of this class contains a large store of information concerning the physical characteristics, mental attributes, habits, customs, arts, beliefs, and institutions of the native Americans. Moreover, research concerning primitive peoples has shown

that the ideas of the savage and barbarous peoples are expressed in the nomenclature much more fully and significantly than are those of cultured peoples, so that the records of personal and geographic names are often of great utility as indices to the intellectual characteristics, customs, and institutions of the Indian tribes; information of this class abounds in America. Thus there is a large store of information in the publications of the early and later travelers in America, but the literature is so vast and so widely scattered that the information is nearly inaccessible to students.

Even before the institution of the Bureau of American Ethnology, ethnologists generally recognized the need of systematic information concerning the aboriginal tribes, and several students had made essays toward the collection of such information from the voluminous literature, either for personal use or for publication. When the Bureau was organized, one of the lines of work projected was the compilation of such information from the published literature and from manuscripts, the compilation being guided and corrected, and the material enriched by concurrent research among the Indians themselves. The bibliographic work undertaken in the Bureau and so long successfully carried forward by Mr. Pilling, was designed largely as a means to this end. In addition, all of the collaborators of the Bureau were instructed, and many correspondents were urged, to obtain and record general facts pertaining to the tribes with which they came in contact; and most of the collaborators of the Bureau have been employed from time to time in collating the material gathered in this way. Anterior to the institution of the Bureau most of the students engaged in systemizing the ethnologic data, arranged the material alphabetically on cards or in books, generally under tribal and other proper names; this was the method pursued by Dr. O. T. Mason, of the Smithsonian Institution, who was engaged in the work before the institution of the Bureau; and essentially the same plan was pursued by Mr. James Mooney during his earlier researches before he became connected with the Bureau.

Under this method of assembling the data, it frequently happened that the records were brief and incomplete and that the terms under which the entries were made were variable, so that much care and thought were necessarily devoted to the ascertainment of synonymy. As the work progressed with the Bureau the studies continued, and the director and collaborators engaged in the compilation came to speak of the work as a "Synonymy" of the Indian tribes. As the material continued to accumulate, and particularly as the more extended and more accurate information gained by actual researches among the Indians was incorporated, it was found that the synonymy proper diminished relatively, while the body of general information became greatly expanded. Now that the records have so increased as to fill several hundred thousand cards, it is found that the work forms a great cyclopedia relating to the Indian tribes, which even in manuscript form is of large and constantly increasing utility. With the development of a plan for publication, as set forth in the last report, the inadequacy of the original name for the work came to be appreciated, and during the present year it has been decided to begin the issue of the work in a series of bulletins corresponding with the aboriginal linguistic stocks, under the designation "Cyclopedia of the American Indians."

Throughout the fiscal year Mr. F. W. Hodge has had charge of the work on the cyclopedia, and during most of the time he has been engaged in preparing the records pertaining to several southwestern stocks for publication. Early in the year Mr. J. Owen Dorsey also contributed to the work, and during July, August, and September, Mr. James Mooney was occupied partly in extending the portion of the cyclopedia relating to the Siouan family. Several bulletins are practically ready for the press, and, save for conditions growing out of the modification of the law governing the public printing, some of these would have been sent to the press before the close of the year.

In 1883 Mr. C. C. Royce was employed in the Bureau to collect and tabulate the various treaties with the Indian tribes relating to the cession and transfer of lands.

The work was substantially completed, and the lands affected by the various treaties described in schedules and platted on maps. These schedules and maps were duly turned in by Mr. Royce and were added to the archives of the office for use in connection with the more strictly ethnologic researches. Since that date frequent requests for information concerning the Indian land treaties have been received, and thereby the value and accuracy of the work has been fully tested. During the year the demand for such information so increased that it was decided to submit the material for publication. While the schedules and maps were in most respects ready for printing, revision of certain portions seemed to be required, and a general introduction was thought to be desirable. Accordingly in November the work of revision was assigned to Dr. Cyrus Thomas, who also undertook the preparation of the requisite introductory chapter. The remainder of the fiscal year was spent by Dr. Thomas chiefly in the completion of this task, which was not quite done at the end of that time. The work is designed for publication as Volume VIII of the Contributions to North American Ethnology.

LINGUISTICS.

As the researches relating to primitive peoples in this and other countries progressed the importance of linguistic studies became more and more apparent. Mankind is preeminent partly because of a variety of individual characteristics, yet in large measure because of social organization; and it is through organization that men have been successively raised from savagery to barbarism, from barbarism to civilization, and from simple civilization to the highest enlightenment and humanity. Now, the basis of organization is expression, and the art of expression is accordingly paramount among the arts of men, and ethnologists have found that the grade of development and the classific relations of peoples are more justly indicated by their arts of oral expression than in any other way. Thus the accepted ethnologic classification in this and other countries is primarily, if not wholly, linguistic.

The importance of linguistic researches has been recognized in the Bureau of American Ethnology from the outset, and much labor has been expended in the collection of linguistic literature as a basis for the classification of the tribes and also as a means for still further extending the principles of ethnic classification.

During the last fiscal year this branch of the work has been carried forward continuously by Dr. Albert S. Gatschet and Mr. J. N. B. Hewitt, and during a part of the year by the Director and Mr. J. Owen Dorsey.

The work of the Director in linguistics during the year was largely ancillary to the researches in psychology and in anthropologic classification. In this connection portions of the rich store of linguistic manuscripts were examined, and the principles of linguistic development were formulated for the use of the collaborators.

Mr. J. Owen Dorsey was occupied during July in (1) the preparation of a catalogue of the Teton-Dakota manuscripts by Messrs. Bushotter and Bruyier, in possession of the Bureau, and (2) the continuation of his work on the Winnebago texts and dictionary slips, noted in previous reports; and during August the first of these lines of work was completed, and he then rearranged the linguistic manuscripts of the fireproof vaults of the Bureau. Many of these manuscripts are unique. A large proportion represent the work of the regular collaborators of the Bureau, but several have been derived from other sources by exchange or by donation, through the interest in the subject developed early in the history of the Bureau. The material is of great scientific value, and it is deemed important that it should be arranged in readily accessible form, in connection with a suitable catalogue. On completing this task, Mr. Dorsey resumed the preparation of material for the synonymy of the Siouan stock, in connection with which he prepared during November a brief memoir on Siouan sociology, which was afterwards revised by Mr. McGee for incorporation in the sixteenth annual report of the Bureau. During December Mr. Dorsey's work was interrupted by illness, which, to the great loss of science, terminated fatally.

At the beginning of the fiscal year Dr. Gatschet was engaged in elaborating the large body of Shawano linguistic material described in preceding reports. This work was continued until the end of September, and a large number of lexic and grammatic elements were extracted and arranged on cards. In connection with this work Dr. Gatschet prepared an ethnographic sketch of the Shawano for incorporation in the cyclopedia of Indian tribes and carried forward his comparative tabulation of the phonetics, grammar, etymology, and syntaxes of all the Algonquian dialects. Special attention was given to this comparative work throughout the remaining portion of the year. During June particular attention was given to the Peoria linguistics, which Dr. Gatschet has continued to elaborate in connection with his comparative work on the Algonquian languages. The studies and comparisons of this material indicate that it is in condition for publication so far as the vocabulary is concerned, though further material will be required before the grammar can be perfected. There is now in the Bureau archives a large body of carefully selected material relating to the Algonquian languages, collected mainly through Dr. Gatschet's persevering industry. Considerable portions of the material are substantially ready for publication; but it seems desirable, before sending the matter to the press, to extend researches concerning certain of the dialects and to introduce the whole by a discussion of the modes of development and the means of dialectic differentiation. A part of the Director's work during the year was contributed toward such an introduction and discussion.

Mr. J. N. B. Hewitt was occupied during a part of the year in transcribing in form for publication the Tubari vocabulary collected during the last fiscal year by Dr. Carl Lumholtz, and in making comparative studies of this and other material obtained by Dr. Lumholtz and other explorers and ethnologists in southwestern United States and Mexico. The task of preparing the Tubari material for publication proved to be great, but was nearly completed during the fiscal year; when ready for printing, the monograph will be an unique and invaluable record of a once numerous tribe, now nearly extinct.

At intervals during the year Mr. Hewitt was engaged in a comparative study of the pronoun as used by various Indian tribes. The pronoun is an important element in primitive speech, and has received much attention from linguists and philologists in many parts of the world. The archives of the Bureau now afford a more extended basis for research concerning this element than is known to exist elsewhere, and this material has been used efficiently and successfully by Mr. Hewitt in his researches. Although the discussion of the subject was well advanced at the close of the fiscal year, it was not yet in form for publication.

MYTHOLOGY.

Mrs. Matilda Coxe Stevenson, whose unfortunate state of health has somewhat impeded the progress of her researches, continued the revision of notes and the final writing of manuscript for her report on the Zuñi Indians. This elaborate report has been in preparation several months. In view of the great number and interest of the ceremonials and the significant nature of the beliefs of the Zuñi Indians, it is thought desirable to spare no pains in making it as nearly exhaustive as possible, and thus all details of ceremonial and belief are receiving attention, necessarily at considerable expense in time.

Mr. Frank Hamilton Cushing, although not completely restored to health, has been engaged in interesting researches concerning the significance of the arrow in primitive thought, custom, and symbolism. Recent investigations of games of divination, American and Oriental, by Mr. Stuart Culin (with whom Mr. Cushing has in some measure cooperated) and by other students in this country and abroad, have shown that among many primitive peoples games are conducted ceremonially rather than for amusement, and that the games are commonly divinatory. The researches have shown also that the arrow, either in itself or by symbol, is an essen-

tial element in such divinatory games. One of the results of these researches is a demonstration of the world-wide use of the arrow and of the existence of close analogies, if not homologies, in fundamental symbolism among the primitive peoples of several continents. The researches also indicate relative recency in origin of many of the games played for amusement among civilized peoples; and they show the origin and successive stages of development of many of these games with remarkable clearness. In scientific research each well-established conclusion gives a new point of view from which the student is able to see further than before into the unknown, and from which also he is able to see relations among the known more clearly than before. This is strictly true of Mr. Cushing's researches concerning the arrow. His preliminary conclusions have afforded insight into various primitive customs and ideas.

PSYCHOLOGY.

Throughout the fiscal year the attention of the Director has been given chiefly to the development of a classification of the races of mankind with special reference to the American tribes. To this end the physical and mental attributes of the tribes were considered in detail; and at the same time the art products were studied as the tangible expression of mental attributes. Pursuing the investigation, it became evident that the distinctive characteristics of individuals, tribes, and peoples, are substantially intellectual. In this way the Director was led to an analysis of the psychic characteristics of mankind. At first the subject was obscure and apparently so complex as to discourage investigation; but as the work progressed, and as arts, organizations, beliefs, and ceremonials, were interpreted as expressions of psychic organization, the causes of apparently unrelated facts fell into order and substantial progress was made in the researches. During recent months it has been found that the researches concerning mental attributes of the American Indians afford a clew to the differentiation of individuals and families, and the coalescence of groups, and the development of individual and collective attributes. Thus the researches in psychology have already yielded a basis for the classification of the native tribes, and have illuminated the aboriginal arts, institutions and beliefs.

Considerable progress has been made in the preparation of an extended report on the classification of the native races and their attributes on a comprehensive psychic basis; but the memoir remained unfinished at the end of the year.

BIBLIOGRAPHY.

Notwithstanding the serious condition of his health, Mr. James C. Pilling continued almost uninterruptedly the compilation of the bibliography of the languages of the North American Indians. The early part of the year was devoted specially to the preparation of the Shahaptian bibliography; but realizing the gradual failure of his strength, Mr. Pilling decided to lay aside this work and to devote his energy to the more important and extensive bibliography of the Mexican languages, and in this labor he was engaged until toward the close of the year, when, his strength having become completely exhausted, he was compelled to abandon it. This bibliography, however, is left in such condition that it is believed the compilation may be made ready for publication without great labor. With the possible exception of the Algonquian bibliography, the bibliography of the Mexican languages will be the most voluminous of the entire series, and many inquiries concerning and applications for the volume have already been made by students. After a long and faithful career in behalf of the Bureau of American Ethnology, the fruits of which are known the world over, Mr. Pilling's services terminated with the close of the month of May.

PUBLICATIONS.

Satisfactory progress was made with the publications of the Bureau during the year, the editorial work being conducted under the immediate direction of the eth-

nologist in charge, aided largely by Mr. F. W. Hodge and Mr. George M. Wood. As stated in my report for the fiscal year ending June 30, 1894, the first proofs of the thirteenth annual report were received from the Public Printer in June; by the beginning of October the entire volume, with the exception of the administrative report and the index, was in page form; the former has since been prepared and transmitted, and the compilation of the index was well under way at the close of the year.

On June 1 the manuscript of the text and illustrations for the fourteenth annual, and on June 14 the copy for the fifteenth annual were transmitted to the printer, but no proofs had been received at the close of the year.

Proof reading of the bulletin bearing the title Chinook Texts, by Franz Boas, was continued from the last fiscal year (when 176 pages were in type), and carried to completion by the middle of December. The edition of this bulletin was delivered in May, 1895.

Final proof reading of the bulletin An Ancient Quarry in Indian Territory, by W. H. Holmes, was also completed, and in October the brochure was ready for distribution.

Early in August the manuscripts of three other bulletins were transmitted to the Public Printer. One of these, the List of Publications of the Bureau of Ethnology, by F. W. Hodge, was received shortly afterward, and in November the edition was delivered. In September the first proofs of Archeologic Investigations in James and Potomac Valleys, by Gerard Fowke, were received. By the close of the year the proof reading was completed, and the edition was delivered by the Government Printing Office in May, 1895. During the same period proof of the bulletin entitled Siouan Tribes of the East, by James Mooney, was read, and the edition received also in May.

To summarize, the following publications were delivered by the Public Printer and transmitted to the regular correspondents of the Bureau during the fiscal year:

Eleventh annual report, for 1889–90, containing, in addition to the Director's report of 25 pages, the following memoirs: (1) The Sia, by Matilda Coxe Stevenson. Pages 3 to 157, Pls. I–XXXV, figs. 1–20. (2) Ethnology of the Ungava District, by Lucien M. Turner. Pages 159 to 349, Pls. XXXVI–XLIII, figs. 21–155.(3) A Study of Siouan Cults, by J. Owen Dorsey. Pages 351 to 544, Pls. XLIV–L, figs. 156–200.

Twelfth annual report, for 1890–91, containing, in addition to the Director's account (28 pages) of the administration of the Bureau during the year, the following: Report on the Mound Explorations of the Bureau of Ethnology, by Cyrus Thomas. Pages 3 to 722, Pls. I–XLII, figs. 1–344.

Contributions to North American Ethnology, Volume IX, comprising Dakota Grammar, Texts, and Ethnography, by S. R. Riggs, edited by J. Owen Dorsey. XXXII, 239 pp.

Bulletin T=20, Chinook Texts, by Franz Boas. 278 pp., 1 pl.

Bulletin U=21, An Ancient Quarry in Indian Territory, by W. H. Holmes. 19 pp., 12 pls., 7 figs.

Bulletin V=22, Siouan Tribes of the East, by James Mooney. 100 pp., map.

Bulletin W=23, Archeologic Investigations in James and Potomac Valleys, by Gerard Fowke. 80 pp., 17 figs.

Bulletin X=24, List of Publications of the Bureau of Ethnology, by F. W. Hodge. 25 pp.

MISCELLANEOUS.

Library.—The growth of the library, mainly through exchange with scientific institutions and individuals throughout the world, has been steady. The number of volumes in possession of the Bureau is 5,029, an increase of 679 volumes since the last fiscal year. The accession of pamphlets and periodicals during the same period has been proportionately great.

Illustrations.—The preparation of illustrations for the publications of the Bureau of American Ethnology has been continued under the direct supervision of Mr. De Lancey W. Gill, to whose artistic skill and intelligent interest in anthropologic subjects the high standard of the pictorial part of the Bureau's published works is largely due.

Photographs.—In addition to the splendid series of photographs made by Mr. Dinwiddie, under the direction of Mr. McGee, during the season of exploration among the Seri and Papago, and those made by Mr. Mindeleff at Canyon de Chelly, individual and group photographs were made of an Osage and an Otoe delegation who visited Washington in February and March, respectively.

NECROLOGY.

Garrick Mallery.—Col. Garrick Mallery, who died at his home in Washington City, October 24, 1894, was born in Wilkesbarre, Pa., April 23, 1831. After his graduation at Yale College and a due course of study under the direction of his father, Judge Garrick Mallery, he began the practice of law in Philadelphia, which he continued until the outbreak of the civil war, when he entered the volunteer service as captain in the Seventy-first Pennsylvania Infantry. Throughout the rebellion Mallery displayed unusual bravery. In June, 1862, at the battle of Peach Orchard, Virginia, he was twice severely wounded, and while lying on the battlefield was captured and sent to Libby Prison, at Richmond, where he remained until exchanged and sent to his home at Philadelphia. As soon as he had sufficiently recovered from his wounds Mallery returned to duty and became lieutenant-colonel of the Thirteenth Pennsylvania Cavalry, which position he retained until the close of the war. In 1866 he was commissioned captain of the Forty-third Infantry of the Regular Army, and later the brevet rank of colonel was bestowed on him for gallant and meritorious services. His scientific knowledge was early recognized by the War Department, and in 1870 he was detailed to execute a plan adopted by law for the prosecution of meteorological researches by the Signal Service, and in this connection frequently acted as chief signal officer of the Army.

Colonel Mallery's studies of the ethnology of the Indians of North America began with his military service on the frontier. In 1876 he was assigned to the command of Fort Rice, Dak., where he became absorbed in the sign language and pictography of the plains tribes. His writings on these subjects soon became well and favorably known, and on the organization of the Bureau of Ethnology in 1879 his services were at once engaged by the director for the prosecution of the researches he had so well begun. In 1880 his Introduction to the Study of Sign Language Among the North American Indians as Illustrating the Gesture Speech of Mankind, was published, followed immediately by A Collection of Gesture Signs and Signals of the North American Indians, with Some Comparisons. The latter volume formed the basis of his memoir on Pictographs of the North American Indians, a preliminary paper of 256 pages published in the fourth annual report of the Bureau, and the greatly extended memoir of 807 pages and over 1,300 illustrations bearing the title Picture Writing of the American Indians—a monument to his industry and ingenious research—comprising the body of the tenth annual report of the Bureau. Colonel Mallery's Sign Language Among North American Indians Compared with that Among other People and Deaf-Mutes, which appeared in the first annual report of the Bureau, was based on his Collection of Gesture Signs and Signals, but even this monograph of 290 pages and 300 illustrations was regarded only as preliminary, his great work on this subject remaining unfinished at the time of his death.

Colonel Mallery was the first to direct serious attention to the investigation of the population of the American aborigines in past times as compared to the present, and his paper, The Former and Present Number of Our Indians, effectually exploded the old theory that the aboriginal population of America at the time of the discovery was much greater than at the present period. But Colonel Mallery's anthropologic researches were not confined to the American Indians. His studies in general soci-

ology show a wide and intimate acquaintance with the literature and peoples of both continents, and his various writings exemplify his scholarly taste and strong power of philosophic comparison. Among the papers pertaining to this subject prepared by Colonel Mallery are: Manners and Meals, Greeting by Gesture, Customs of Courtesy, Philosophy and Specialties, and The Gesture Speech of Man. His study, "Israelite and Indian—a parallel in planes of culture," provoked much discussion among scientific men, and was translated into the German by Dr. Frederick S. Krauss.

In the words of a life-long friend, Garrick Mallery was "the gallant soldier with a stainless record; the scholar largely read in the literature of his own and other times; the man of science who has left an imperishable record of ingenious and far-reaching research; the trusted councilor in the societies which honored him with their highest dignities; the genial companion; the affectionate husband; the staunch friend; the high-bred gentleman."

James Owen Dorsey.—In the death of Mr. Dorsey American ethnology lost a brilliant student. Born in Baltimore October 31, 1848, he acquired his primary education in the schools of his native city. At an early age he evinced a marked precocity in the acquirement of language; it is said that at 6 he learned the Hebrew alphabet, and ere he reached his eleventh year he could read the language with facility. At 14 young Dorsey entered the Central High School, now City College, and pursued the classic course, but during his second year he was constrained to abandon his studies by reason of ill health. In the autumn of 1867 he entered the preparatory department of the Theological Seminary of Virginia, and the junior class in 1869. Two years later he was ordained a deacon of the Protestant Episcopal Church, and in May began mission work among the Ponka Indians of Dakota Territory. But the rigorous climate and the vicissitudes of early frontier life soon affected his health, which was never robust, and after serious attacks of illness in July, 1872, and early in 1873, he was compelled to abandon his mission work in August of the latter year, soon after he had acquired the ability to converse with the Indians without the aid or an interpreter. Returning to Maryland he was engaged in parish work until July, 1878.

While pursuing his work as missionary among the Indians, Mr. Dorsey became a correspondent of the Smithsonian Institution. His profound knowledge of the dialects of the Siouan languages early attracted the attention of Maj. J. W. Powell, at whose instance he was sent among the Omaha tribe in 1878 for the purpose of acquiring additional linguistic and other anthropologic material, remaining among that people until the spring of 1880. In the meantime, upon the organization of the Bureau of Ethnology, in 1879, he was immediately chosen one of the scientific corps and was arduously engaged in linguistic and sociologic work up to the time of the illness which terminated in his death in this city on February 4, 1895.

His great modesty and his strong conviction that the views of a student should be molded by truths prevented him from formulating subjective theories by which to judge the value of his facts. In the later years of his studies in linguistic morphology he began to feel the inadequacy of the venerable agglutination theory to explain all the facts of word structure prevailing in the languages he was studying, and he came to look upon adaptation—the infusing with a new meaning or function an element which before had or had not any definite signification—as an important and potent factor in the genesis and development of morphologic structures. His mastery of the wealth of forms in the languages he studied enabled him to illustrate copiously the working of this principle. His linguistic acumen and painstaking accuracy are brought out in his interlinear translations of numerous and voluminous texts, both in print and in manuscript. His marvelous aptitude in discriminating, grasping, and retaining sounds enabled him to obtain accurate vocabularies and texts with great ease, and to detect differences of meaning and function through differences of sound. His freedom from subjective theories, his deep erudition, and enlightened conservatism made him one of the foremost authorities in American linguistics.

In addition to numerous essays dealing with the linguistic and other anthropologic matters which appeared from time to time in various periodicals, Mr. Dorsey published under the auspices of the Bureau of Ethnology the following excellent and suggestive memoirs: Omaha Sociology, Osage Traditions, A Study of Siouan Cults, Omaha Dwellings, Furniture, and Implements; Omaha and Ponka Letters, and The Dhegiha Language, with Myths, Stories, and Letters. He also edited the Dakota-English Dictionary, and Dakota Grammar, Texts, and Ethnography of the late Rev. S. R. Riggs, forming, respectively, Volumes VII and IX of Contributions to North American Ethnology. At the time of his death he had completed a paper on Siouan sociology. Among the papers and articles of marked importance published in extra-governmental media may be mentioned Migrations of Siouan Tribes, Comparative Phonology of Four Siouan Languages, An Account of the War Customs of the Osages, and Mourning and War Customs of the Kansas.

By reason of the purity and unselfishness of his motives, and the warmth and sunshine of his amiable nature, he won the esteem of all who had the pleasure of meeting him, and, being ever kind, affable, and cheerful to his colleagues, ever willing to aid and advise them, James Owen Dorsey was sincerely and cordially loved and revered by all.

Very respectfully,

J. W. POWELL,
Director.

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

APPENDIX III.

REPORT OF THE CURATOR OF EXCHANGES FOR THE YEAR ENDING JUNE 30, 1895.

SIR: I have the honor to present the following report upon the operations of the Bureau of International Exchanges for the fiscal year ending June 30, 1895. It is confined almost entirely to the presentation of statistics, compiled upon the plan established in 1888.

The actual number of packages received during the year was somewhat over 9,000 (or 8 per cent) more than during the year preceding, the increase in the weight of packages being nearly 92,000 pounds. This increase was due in part to the transmission of a considerable number of packages which, on account of insufficient appropriation, had to be declined during the preceding year, and more especially to the transmission of the Congressional Library exchange, including a large number of packages that had accumulated. Four hundred and fifty-nine more cases were shipped abroad than during any previous year.

TABULAR STATEMENT OF THE WORK OF THE BUREAU.

The work of the Bureau is succinctly given in the annexed table, prepared in a form adopted in preceding reports:

Transactions of the Bureau of International Exchanges during the fiscal year 1894–95.

Date.	Number of packages received.	Weight of packages received.	Ledger cards from January 1, 1892.				Domestic packages sent.	Invoices written.	Cases shipped abroad.	Letters received.	Letters sent.
			Foreign societies.	Domestic societies.	Foreign individuals.	Domestic individuals.					
1894.											
July	8,948	27,037	......	......	......	......	....	....	......	199	108
August	14,825	40,107	......	......	......	......	....	....	......	162	204
September	10,749	60,762	......	......	......	......	....	....	......	116	127
October	6,841	17,824	......	......	......	......	....	....	......	214	226
November	8,132	18,642	......	......	......	......	....	....	......	208	211
December	7,108	16,266	......	......	......	......	....	....	......	203	145
1895.											
January	10,500	27,749	......	......	......	......	....	....	......	283	190
February	8,038	17,742	......	......	......	......	....	....	......	184	229
March	7,792	27,893	......	......	......	......	....	....	......	217	162
April	6,920	13,641	......	......	......	......	....	....	......	195	152
May	5,405	17,938	......	......	......	......	....	....	......	245	221
June	11,860	41,354	......	......	......	......	....	....	......	217	284
Total	107,118	326,955	8,751	2,014	9,609	3,034	29,111	27,180	1,364	2,443	2,259
Increase over 1893–94	9,149	91,927	1,760	394	990	41	*a* 3,820	6,311	459	277	355

a Decrease.

For comparison with previous years, I add a statement from 1889 to 1895, which will make apparent the growth of the service:

	1888–89.	1889–90.	1890–91.	1891–92.	1892–93.	1893–94.	1894–95.
Number of packages received..	75, 966	82, 572	90, 666	97, 027	101, 063	97, 969	107, 118
Weight of packages received..	179, 928	202. 657	237, 612	226, 517	200, 928	235. 028	326, 955
Ledger accounts:							
Foreign societies	4, 466	5, 131	5, 981	6, 204	6, 896	6, 991	8 751
Foreign individuals	4, 699	6, 340	7, 072	7, 910	8, 554	8, 619	9, 609
Domestic societies..........	1, 355	1, 431	1, 588	2, 044	2, 414	1, 620	2, 014
Domestic individuals......	2, 610	3, 100	4, 207	4, 524	5, 010	2, 993	3, 034
Domestic packages sent.......	17, 218	13, 216	29, 047	26, 000	29, 454	32, 931	29, 111
Invoices written................	14, 095	16, 948	21, 923	23, 136	19, 996	20, 869	27, 180
Cases shipped abroad..........	693	873	962	1, 015	878	905	1, 364
Letters received................	1, 214	1, 509	2, 207	2, 323	2, 013	2, 166	2, 443
Letters written.................	2, 050	1, 625	2, 417	2, 752	2, 259	1, 904	2, 259

EXPENSES.

The expense of the exchange system is met in part by direct appropriation by Congress to the Smithsonian Institution for the purpose, and in part by appropriations made to different Government Departments or Bureaus, either in their contingent funds or in specific terms for repayment to the Institution for a portion of the cost of transportation.

In 1878 the Board of Regents established a charge of 5 cents per pound weight for the publications sent out or received by the various Government Bureaus, this charge being necessary to prevent an undue tax upon the resources of the Institution. For similar reasons it has been found necessary to make a charge of like amount to State institutions, from which a further small revenue has been derived.

The appropriation made by Congress to the Institution for the exchange service for the fiscal year 1894–95 was in the following terms:

"For expenses of the system of international exchanges between the United States and foreign countries, under the direction of the Smithsonian Institution, including salaries or compensation of all necessary employees, seventeen thousand dollars."

The receipts and disbursements by the accounting officer of the Smithsonian Institution on account of international exchanges, under date of July 1, 1895, covering the fiscal year immediately preceding, were as follows:

RECEIPTS.

Direct appropriation by Congress	$17, 000. 00
Repayment to the Smithsonian Institution from United States Government Departments..	5, 327. 54
State institutions..	35. 50
From other sources..	297. 84
Total	22, 660. 88

EXPENSES.

From specific Congressional appropriations:	
Salaries and compensation	$13,594.84
Freight	1,849.91
Packing boxes	791.28
Printing	31.60
Postage	260.00
Stationery and supplies	470.36
Total disbursements	16,997.99
Balance to meet outstanding liabilities June 30, 1895	2.01
From other sources	4,092.62
Balance	1,568.26
Total	22,660.88

The foregoing table shows that the entire amount received from Government Bureaus and other sources was $5,660.88, which added to the appropriation of $17,000 makes the sum practically available for the specific purpose of exchanges $22,660.88, while the expenses amounted to $21,090.61, the balance being held for repayment to the Smithsonian Institution of the sum $944.36, which was advanced in the year 1893–94 to enable the Bureau to carry on its operations, and for other outstanding liabilities.

CORRESPONDENTS.

As mentioned in previous reports, it became necessary in the latter part of 1891 to provide for an addition to the series of "ledger" cards upon which were entered all packages sent or received from a given society or individual. A plan was approved by which the cards were much reduced in size, the bulk of the older cards having already become a matter of serious consideration.

The new and smaller ledger cards were begun on January 1, 1892, and since that date all the transactions have been entered upon them. The abbreviation of the records and their greater convenience in handling proved to be of the utmost service when it became necessary to reduce the clerical force in the office, and it is only by such abbreviation of the records and by the introduction of several minor labor-saving devices that it has been at all possible to prevent the work from falling seriously behind.

The number of ledger cards on June 30, 1894, was 20,223, and on June 30, 1895, 23,408. The difference of 3,185 represents the increase in the number of new societies or individuals upon the exchange lists during the year making use of the service, while the entire number of cards (23,408) is the number of societies and individuals, both domestic and foreign, with which the exchange office has had relations since January 1, 1892.

Attention has been directed for some time past to the fact that the list of correspondents in the exchange office requires revision and recopying upon cards, the original office list prepared and printed in 1886 having become so worn and so overcrowded by frequent interlineations as to be almost illegible. This revision was authorized by the Secretary in March, 1895, and the work was completed by Mr. Boehmer before the expiration of the fiscal year.

The statistical statement of this work shows the existence of 23,408 names, of which 10,765 are establishments and 12,643 individuals. They are located in 3,771 places, embracing all parts of the world from Disco, Greenland, in north latitude 70°, to Port Stanley, Falkland Islands, in latitude 50° south, and extending east and west to 178° and 170°, respectively. A recapitulation of the work is given in the following table:

Correspondents of the Bureau of International Exchanges.

Country.	Places.	Correspondents. Libraries.	Correspondents. Individuals.	Correspondents. Total.
AFRICA.				
Algeria	8	22	18	40
Azores	7	2	9	11
Canary Islands	4	1	5	6
Cape Colony	18	35	43	78
Cape Verde Islands	4	....	5	5
Congo	3	....	4	4
East Africa	1	....	2	2
Egypt	13	23	35	58
Gambia	1	....	2	2
Gold Coast	1	....	1	1
Guinea	1	....	1	1
Isle of Reunion	1	1	....	1
Liberia	2	2	4	6
Madagascar	6	3	4	7
Madeira	1	1	4	5
Malta	4	8	13	21
Mauritius	3	10	7	17
Morocco	8	....	9	9
Mozambique	1	1	1	2
Natal	4	5	8	13
Orange Free State	1	....	1	1
Niger Territory	1	1	....	1
St. Helena	1	1	3	4
San Paulo de Loando	1	1	....	1
Sechelles Islands	1	1	....	1
Senegal	1	1	....	1
Sierra Leone	1	1	2	3
South African Republic	3	5	3	8
Tunis	1	2	3	5
Zanzibar	1	....	5	5
AMERICA.				
North America:				
Greenland	3	....	3	3
British America	119	186	275	461
United States	1,113	2,014	3,034	5,048
Mexico	35	104	76	180
Central America:				
British Honduras	1	2	4	6
Costa Rica	4	21	24	45
Guatemala	6	35	44	79
Honduras	13	6	19	25
Nicaragua	10	9	21	30
San Salvador	5	8	8	16
West Indies (combined)	94	70	220	290
South America:				
Argentina	11	68	62	130
Bolivia	4	6	2	8
Brazil	26	73	71	144
British Guiana	4	14	5	19
Chile	15	50	60	110
Colombia	13	26	34	60
Dutch Guiana	3	4	2	6
Ecuador	5	8	9	17

Correspondents of the Bureau of International Exchanges—Continued.

Country.	Places.	Correspondents.		
		Libraries.	Individuals.	Total.
AMERICA—continued.				
South America—Continued.				
Falkland Islands	2		5	5
French Guiana	1		2	2
Paraguay	1	8	5	13
Peru	11	22	27	49
Uruguay	4	23	18	41
Venezuela	16	20	29	49
ASIA.				
Arabia	3		6	6
British Burmah	3	6	7	13
British North Borneo	1		1	1
Ceylon	10	17	8	25
China	21	30	54	84
Cochin-China	4	5	4	9
Corea	1	1	5	6
Cyprus	1	1	2	3
India	56	145	98	243
Japan	28	72	128	200
Netherlands Indies	10	13	17	30
Persia	3	1	5	6
Philippine Islands	3	6	9	15
Siam	1	1	5	6
Straits Settlements	5	10	10	20
AUSTRALASIA.				
New South Wales	15	51	69	120
Queensland	6	26	29	55
South Australia	11	30	44	74
Tasmania	4	13	21	34
Victoria	12	74	62	136
West Australia	3	7	2	9
New Guinea	1		1	1
New Zealand	18	59	27	86
POLYNESIA.				
Fiji Islands	1		3	3
Marshall Islands	1		1	1
New Caledonia	1		3	3
Samoa	2		5	5
Sandwich Islands	9	14	32	46
Society Islands	1		1	1
EUROPE.				
Austria-Hungary	122	532	506	1,038
Belgium	49	231	242	473
Bulgaria	7	12	6	18
Denmark	17	83	104	187
France	287	1,277	1,134	2,411
Germany	370	1,854	1,496	3,350
Great Britain and Ireland:				
England	457	1,209	2,143	3,352
Ireland	34	92	116	208
Scotland	45	145	238	383
Wales	19	18	23	41

Correspondents of the Bureau of International Exchanges—Continued.

Country.	Places.	Correspondents. Libraries.	Individuals.	Total.
EUROPE—continued.				
Gibraltar	1	....	2	2
Greece	9	35	27	62
Iceland	5	16	7	23
Italy	106	511	488	999
Netherlands	40	140	161	301
Norway	16	98	74	172
Portugal	7	82	57	139
Roumania	4	22	19	41
Russia	92	341	298	639
Servia	1	12	5	17
Spain	45	134	96	230
Sweden	42	141	158	299
Switzerland	86	239	283	524
Turkey	22	24	48	72
International	31	31	....	31
Total	3,771	10,765	12,643	23,408

The special exchange list for the distribution of Smithsonian documents is also in need of revision and correction. It was prepared many years ago, and not a few of the libraries to which it was deemed proper at the time to send these publications have sunk into obscurity, while many new libraries have been established to which it seems desirable that Smithsonian documents should be sent. A considerable number of requests are received each year inviting an exchange of publications, or requests for the completion of the Smithsonian series of documents, with which it is rarely practicable to comply. This work has been begun, but had not been completed at the close of the year.

INTERNATIONAL EXCHANGE OF OFFICIAL DOCUMENTS.

Under the treaty of Brussels of 1886, the text of which is given below,* the exchange of the official publications of the United States Government with other countries has been continued by the Institution, and it now forms a very large proportion of the Bureau's work.

*CONVENTION CONCERNING THE INTERNATIONAL EXCHANGES FOR OFFICIAL DOCUMENTS AND SCIENTIFIC AND LITERARY PUBLICATIONS.

[Translation from the French.]

The President of the United States of America, His Majesty the King of the Belgians, His Majesty the Emperor of Brazil, Her Majesty the Queen Regent of Spain, His Majesty the King of Italy, His Majesty the King of Portugal and of the Algarves, His Majesty the King of Servia, the Federal Council of the Swiss Confederation, desiring to establish, on the basis adopted by the conference which met at Brussels from the 10th to the 14th April, 1883, a system of international exchanges of the official documents and of the scientific and literary publications of their respective States, have appointed for their plenipotentiaries, to wit:

The President of the United States of America, Mr. Lambert Tree, minister resident of the United States of America at Brussels; His Majesty the King of the Belgians,

The entire number of publications sent abroad during the year under the provisions of the act of Congress of March 2, 1867, and of the treaty above referred to, was 23,023, and there have been received in return 974 packages. The United States Government Departments have forwarded to their correspondents abroad 37,871 packages, and have received in return 14,813 packages. The total number of exchanges for Government libraries has therefore been 15,787 packages received and 37,871 packages sent abroad, a total of 76,681 packages, or about 71 per cent of the entire number handled.

The very inadequate return for the great number of documents sent out is in part undoubtedly due to the fact that no other country publishes on such a lavish scale as our own. Direct solicitation made by a special representative to the Governments with which the Institution is in correspondence would also probably result in a considerable increase to the Library of Congress.

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the Prince de Caraman, his minister of foreign affairs, and the Chevalier de Moreau, his minister of agriculture, industry, and public works,

His Majesty the Emperor of Brazil, the Count de Villeneuve, his envoy extraordinary and minister plenipotentiary near His Majesty the King of the Belgians,

Her Majesty the Queen Regent of Spain, Mr. de Tavira, chargé d'affaires ad interim of Spain at Brussels,

His Majesty the King of Italy, the Marquis Maffei, his envoy extraordinary and minister plenipotentiary near His Majesty the King of the Belgians,

His Majesty the King of Portugal and of the Algarves, the Baron de Sant'Anna, envoy extraordinary and minister plenipotentiary of His Very Faithful Majesty,

His Majesty the King of Servia, Mr. Marinovitch, his envoy extraordinary and minister plenipotentiary near His Majesty the King of the Belgians,

The Federal Council of the Swiss Confederation, Mr. Rivier, its special plenipotentiary,

Who, after having communicated between themselves their full powers, which are found in good and due form, have agreed upon the following articles:

ARTICLE I. There shall be established in each of the contracting States, a bureau charged with the duty of the exchanges.

ART. II. The publications which the contracting States agree to exchange are the following:

1st. The official documents, parliamentary and administrative, which are published in the country of their origin.

2nd. The works executed by order and at the expense of the Government.

ART. III. Each bureau shall cause to be printed a list of the publications that it is able to place at the disposal of the contracting States.

This list shall be corrected and completed each year and regularly addressed to all the bureaus of exchange.

ART. IV. The bureaus of exchange will arrange between themselves the number of copies which they may be able eventually to demand and furnish.

ART. V. The transmission shall be made directly from bureau to bureau. Uniform models and formulas will be adopted for the memoranda of the contents of the cases, as well as for all the administrative correspondence, requests, acknowledgments of reception, etc.

ART. VI. For exterior transmissions, each State assumes the expense of packing and transportation to the place of destination. Nevertheless, when the transmissions shall be made by sea, special arrangements will regulate the share of each State in the expense of transportation.

ART. VII. The bureaus of exchange will serve, in an official capacity, as intermediaries between the learned bodies and literary and scientific societies, etc., of the contracting States for the reception and transmission of their publications.

It remains, however, well understood that, in such case, the duty of the bureaus of exchange will be confined to the free transmission of the works exchanged, and

A large surplus of Government documents available for foreign exchanges has now accumulated, the number of foreign Governments with which exchange relations have been arranged not requiring at present the entire number received from the printing office. The proper storage of these documents has now become a serious problem.

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that these bureaus will not in any manner take the initiative to bring about the establishment of such relations.

ART. VIII. These provisions apply only to the documents and works published after the date of the present convention.

ART. IX. The States which have not taken part in the present convention are admitted to adhere to it on their request.

This adhesion will be notified diplomatically to the Belgian Government, and by that Government to all the other signatory States.

ART. X. The present convention will be ratified and the ratifications will be exchanged at Brussels as soon as practicable. It is concluded for ten years from the day of the exchange of ratifications, and it will remain in force beyond that time, so long as one of the Governments shall not have declared six months in advance that it renounces it.

In witness whereof the respective plenipotentiaries have signed it and have thereunto affixed their seals.

Done at Brussels in eight copies the 15th of March, 1886.

LAMBERT TREE.	[SEAL.]	JOSÉ MA. DE TAVIRA.	[SEAL.]
PR. DE CARAMAN.	[SEAL.]	MAFFEI.	[SEAL.]
CHEVALIER DE MOREAU.	[SEAL.]	BARON DE SANT'ANNA.	[SEAL.]
COMTE DE VILLENEUVE.	[SEAL.]	I. MARINOVITCH.	[SEAL.]
		ALPHONSE RIVIER.	[SEAL.]

The exchange on account of Government bureaus is shown in detail in the following table:

Statement of Government exchanges during the year 1894–95.

Name of bureau.	Packages— Received for.	Packages— Sent by.	Name of bureau.	Packages— Received for.	Packages— Sent by.
Commissioners of the District of Columbia	3	....	U. S. Geological Survey	465	5,455
Smithsonian Institution	12,694	6,399	U. S. Hydrographic Office	79	....
Bureau of Ethnology	190	2,776	U. S. Indian Affairs Office	5	....
Bureau of International Exchanges	2	....	U. S. Inspector-General's Office, War Department	....	1
National Zoological Park	1	....	U. S. Interior Department	22	663
U. S. Agricultural Department	220	12,739	U. S. Interstate Commerce Commission	6	156
U. S. Army Medical Museum	1	....	U. S. Light-House Board	2	2
U. S. Botanic Garden	1	....	U. S. Marine-Hospital Service	3	....
U. S. Bureau of American Republics	1	....	U. S. Mint	2	....
U. S. Bureau of Education	96	....	U. S. National Academy	66	294
U. S. Bureau of Medicine and Surgery	2	....	U. S. National Board of Health	1	....
U. S. Bureau of Navigation	3	....	U. S. National Museum	215	2,929
U. S. Bureau of Ordnance, Navy Department	1	....	U. S. Nautical Almanac Office	19	193
U. S. Bureau of Ordnance, War Department	1	....	U. S. Naval Intelligence Office	1	....
U. S. Bureau of Statistics, Treasury Department	30	....	U. S. Naval Observatory	98	....
U. S. Census Office	7	1	U. S. Navy Department	7	....
U. S. Coast and Geodetic Survey	95	21	U. S. Patent Office	53	4,069
U. S. Comptroller of the Currency	4	....	U. S. President	3	....
U. S. Congressional Library	974	....	U. S. Public Printer	....	23,023
U. S. Department of Labor	34	53	U. S. Signal Service	33	....
U. S. Department of Steam Engineering, Navy Department	1	....	U. S. State Department	15	....
U. S. Engineer Office	40	2	U. S. Surgeon-General's Office (Army)	122	548
U. S. Entomological Commission	5	....	U. S. Surgeon-General's Office (Navy)	2	....
U. S. Fish Commission	61	443	U. S. Treasury Department	7	....
U. S. General Land Office	4	7	U. S. Vice-President	1	....
			U. S. War Department	11	251
			U. S. War Records Office	26	74
			U. S. Weather Bureau	52	795
			Total	15,787	60,894

EFFICIENCY OF THE SERVICE.

I venture to again call attention to the unsatisfactory condition of the exchange relations with Greece, which are in the same state as a year ago, when, on account of the expenses attending the distribution of packages, the transmission of miscellaneous exchanges was discontinued by request of the librarian of the United National and University libraries, formerly acting as the medium for distributing publications.

The exchange with Mexico is still also in an extremely unsatisfactory condition, and the transmission of the parliamentary documents to the Mexican Government has been suspended awaiting some action by the Mexican authorities, to whose attention the matter was brought through the Mexican minister.

I am glad to report that the comparatively large repayments made to the Smithsonian Institution by Government bureaus for the transmission of their exchanges have enabled the Bureau to employ some additional assistance, by which means it has become possible to bring up to a great extent the records that during the past year had fallen into arrears. It was also found practicable to make a slight increase in the regular working force of the Bureau, and I take pleasure in bearing witness to the efficiency of the employees in the exchange office, and in expressing apprecia-

tion of their efforts to dispose of all the accumulations of the preceding year and to keep up with the added volume of work, and I beg leave to call to your notice the careful attention to the interests of the Institution on the part of its special agents abroad, Dr. Felix Flügel, in Leipsic, and Messrs. William Wesley & Son, in London.

Grateful acknowledgments are also due to the following transportation companies and others for their liberality in granting the privilege of free freight or in otherwise assisting in the transmission of exchange parcels and boxes, while to other firms thanks are due for reduced rates of transportation in consideration of the disinterested services of the Institution in the diffusion of knowledge:

LIST OF SHIPPING AGENTS AND CONSULS TO WHOM THE EXCHANGE SERVICE IS INDEBTED FOR SPECIAL COURTESIES.

Royal Portuguese consul-general, New York.
American Board of Commissioners for Foreign Missions, Boston.
Anchor Steamship Line (Henderson & Bro., agents), New York.
Atlas Steamship Company (Pim, Forwood & Co.), New York.
Bailey, H. B., & Co., New York.
Börs, C., consul-general for Sweden and Norway, New York.
Boulton, Bliss & Dallett, New York.
Calderon, Climaco, consul-general for Colombia, New York.
Cameron, R. W., & Co., New York.
Baltazzi, X., consul-general for Turkey, New York.
Columbian Line (Stamford Parry, Herron & Co., agents), New York.
Compagnie Générale Transatlantique (A. Forget, agent), New York.
Cunard Royal Mail Steamship Company (Vernon H. Brown & Co., agents), New York.
Espriella, Justo R. de la, consul-general for Chile, New York.
Hamburg-American Packet Company (R. J. Cortis, manager), New York.
Hensel, Bruckmann & Lorbacher, New York.
Consul-general for Uruguay, Baltimore, Md.
Muñoz y Espriella, New York.
Navigazione Generale Italiana (Phelps Bros. & Co.), New York.
Netherlands-American Steam Navigation Company (W. H. Vanden Toorn, agent), New York.
North German Lloyd (agents: Oelrichs & Co., New York; A. Schumacher & Co., Baltimore).
Obarrio, Melchor, consul-general for Bolivia, New York.
Pacific Mail Steamship Company (H. J. Bullay, superintendent), New York.
Pioneer Line (R. W. Cameron & Co.), New York.
Perry, Ed., & Co., New York.
Pomares, Mariano, consul-general for Salvador, New York.
Red Star Line (Peter Wright & Sons, agents), New York and Philadelphia.
Röhl, C., consul-general for Argentina, New York.
Royal Danish consul, New York.
Ruiz, Domingo L., consul-general for Ecuador.
Stewart, Alexander, consul-general for Paraguay, Wachington, D. C.
Toriello, Enrique, consul-general for Guatemala, New York.
White Cross Line of Antwerp (Funch, Edye & Co.), New York.

LIST OF THE CORRESPONDENTS OF THE SMITHSONIAN THROUGH WHOM INTERNATIONAL EXCHANGES ARE TRANSMITTED.

Algeria: Bureau Français des Échanges Internationaux, Paris, France.
Argentina: Museo Nacional, Buenos Ayres.
Austria-Hungary: Dr. Felix Flügel, Schenkendorf-Strasse 9, Leipzig, Germany.
Brazil: Bibliotheca Nacional, Rio Janeiro.
Belgium: Commission des Échanges Internationaux, Rue du Musée, No. 5, Brussels.
Bolivia: University, Chuquisaca.
British America: McGill College, Montreal, and Geological Survey Office, Ottawa.
British Colonies: Crown Agents for the Colonies, London, England.

British Guiana: Government Laboratory, Georgetown.
Cape Colony: Colonial Secretary, Cape Town.
Chile: Museo Nacional, Santiago.
China: Zi-ka-wei Observatory, Shanghai.
Colombia (United States of): National Library, Bogota.
Costa Rica: Oficina de Deposito, Reparto y Canje International, San José.
Cuba: Dr. Federico Poey, Calle del Rayo, 19, Habana, Cuba.
Denmark: Kongelige Danske Videnskabernes Selskab, Copenhagen.
Dutch Guiana: Surinaamsche Koloniale Bibliotheek, Paramaribo.
East India: Director-General of Stores, India Office, London.
Ecuador: Observatorio del Colegio Nacional, Quito.
Egypt: Société Khédiviale de Géographie, Cairo.
France: Bureau Français des Échanges Internationaux, Paris.
Germany: Dr. Felix Flügel, Schenkendorf-Strasse 9, Leipzig.
Great Britain and Ireland: William Wesley & Son, 28 Essex street, Strand, London.
Guadeloupe. (*See* France.)
Guatemala: Instituto Nacional de Guatemala, Guatemala.
Haiti: Secrétaire d'État des Rélations Extérieures, Port-au-Prince.
Honduras: Biblioteca Nacional, Tegucigalpa.
Iceland: Icelands Stiptisbokasáfn, Reykjavík.
Italy: Biblioteca Nazionale Vittorio Emanuele, Rome.
Japan: Minister of Foreign Affairs, Tokyo.
Java. (*See* Netherlands.)
Liberia: Liberia College, Monrovia.
Madeira: Director-General, Army Medical Department, London, England.
Malta. (*See* British Colonies.)
Mauritius: Royal Society of Arts and Sciences, Port Louis.
Mexico: Packages sent by mail.
Mozambique: Sociedad de Geografia, Mozambique.
Netherlands: Bureau Scientifique Central Néerlandais, Den Helder.
New Caledonia: Gordon & Gotch, London, England.
Newfoundland: Postmaster-General, St. Johns.
New South Wales: Government Board for International Exchanges, Sydney.
New Zealand: Colonial Museum, Wellington.
Nicaragua: Ministerio de Relaciones Exteriores, Managua.
Norway: Kongelige Norske Frederiks Universitet, Christiania.
Paraguay: Government, Asuncion.
Peru: Biblioteca Nacional, Lima.
Philippine Islands: Royal Economical Society, Manila.
Polynesia: Department of Foreign Affairs, Honolulu.
Portugal: Bibliotheca Nacional, Lisbon.
Queensland: Government Meteorological Observatory, Brisbane.
Roumania. (*See* Germany.)
Russia: Commission Russe des Échanges Internationaux, Bibliothèque Impériale Publique, St. Petersburg.
St. Helena: Director-General, Army Medical Department, London, England.
San Salvador: Museo Nacional, San Salvador.
Servia. (*See* Germany.)
South Australia: Astronomical Observatory, Adelaide.
Spain: R. Academia de Ciencias, Madrid.
Sweden: Kongliga Svenska Vetenskaps Akademien, Stockholm.
Switzerland: Central Library, Berne.
Tasmania: Royal Society of Tasmania, Hobarton.
Turkey: American Board of Commissioners for Foreign Missions, Boston, Mass.
Uruguay: Oficina de Depósito, Reparto y Canje Internacional, Montevideo.
Venezuela: Museo Nacional, A. Ernst, Director, Caracas.
Victoria: Public Library, Museum and National Gallery, Melbourne.

Transmissions of exchanges to foreign countries.

Country.	Date of transmission, etc.
Argentina	October 30, 1894; June 18, 1895.
Austria-Hungary	July 13, 23, September 8, 17, 29, October 1, November 17, 28, December 4, 1894; February 9, March 13, 19, April 22, May 3, 17, June 4, 1895.
Belgium	September 29, October 1, December 5, 1894; January 3, March 19, April 4, May 3, 1895.
Bolivia	October 30, 1894.
Brazil	October 30, 1894; June 18, 1895.
British colonies	September 29, December 12, 31, 1894; January 24, February 25, April 9, June 6, 1895.
Cape Colony	September 29, November 6, 1894; May 20, 1895.
China	September 29, November 3, December 5, 1894; March 7, May 9, 1895.
Chile	October 30, 1894; June 18, 1895.
Colombia	October 30, 1894; June 18, 1895.
Costa Rica	September 29, 1894; January 19, 1895.
Cuba	January 19, 1895.
Denmark	September 29, October 1, November 17, 1894; January 7, March 28, 1895.
East India	November 21, 1894; May 9, 24, 1895.
Ecuador	October 30, 1894; June 18, 1895.
Egypt	September 29, November 6, 1894; May 20, 1895.
France and colonies	July 18, September 8, 11, 29, October 17, November 15, December 5, 1894; January 12, 28, February 9, March 5, 19, April 29, May 20, 1895.
Germany	July 13, 23, September 8, 17, 29, October 1, 18, 1894; January 2, 17, February 9, March 13, 19, April 22, May 3, June 4, 1895.
Greece	October 26, 1894.
Great Britain	July 12, September 8, 29, October 1, 13, 19, November 6, December 3, 12, 31, 1894; January 24, February 8, 25, March 18, 22, April 1, 19, May 15, 20, 24, June 10, 12, 1895.
Guatemala	February 8, 1895.
Haiti	January 19, 1895.
Honduras	September 29, 1894; January 19, 1895.
Italy	August 2, September 8, 29, November 17, December 5, 18, 1894; January 28, February 9, March 22, April 6, May 3, 17, 1895.
Japan	August 28, September 29, November 3, December 5, 1894; March 7, May 9, 1895.
Liberia	November 6, 1894; May 20, 1895.
Mexico	(By registered mail.)
New South Wales	July 31, September 29, 1894; February 8, 1895.
Netherlands and colonies	September 29, October 1, December 24, 1894; March 25, 1895.
New Zealand	July 31, September 29, 1894; February 8, 1895.
Nicaragua	January 19, February 8, 1895.
Norway	August 4, September 29, October 1, 1894; January 8, April 1, 1895.
Paraguay	October 30, 1894; June 18, 1895.
Peru	October 30, 1894; June 18, 1895.
Polynesia	July 31, 1894; February 8, 1895.
Portugal	September 29, October 1, 1894; January 8, March 29, 1895.
Queensland	July 31, September 29, December 5, 1894; February 8, 1895.
Roumania	(Included in Germany.)
Russia	September 29, October 1, November 10, 1894; January 15, March 22, May 2, 1895.
South Australia	July 31, September 29, 1894; February 8, 1895.
Spain	September 29, October 1, 1894; January 8, March 29, 1895.
Sweden	August 4, September 29, October 1, November 15, December 5, 1894; January 15, February 9, March 22, May 3, 1895.
Switzerland	September 29, October 1, November 17, 1894; January 5, March 28, 1895.
Tasmania	July 19, 1894; February 8, 1895.
Turkey	January 8, May 21, 1895.
Uruguay	October 30, 1894; June 18, 1895.
Venezuela	July 20, October 30, 1894; June 18, 1895.
Victoria	July 31, September 29, 1894; February 8, 1895.

The distribution of exchanges to foreign countries was made in 1,112 cases, representing 160 transmissions, as follows:

Argentina	17	Japan	36
Austria-Hungary	72	Liberia	2
Belgium	25	Mexico (by mail).	
Bolivia	1	New South Wales	13
Brazil	21	Netherlands and Colonies	27
British Colonies	8	New Zealand	8
Cape Colony	5	Nicaragua	5
China	4	Norway	19
Chile	8	Paraguay	2
Colombia	3	Peru	3
Costa Rica	4	Polynesia	3
Cuba	3	Portugal	12
Denmark	19	Queensland	8
East India	22	Roumania (included in Germany).	
Ecuador	2	Russia	38
Egypt	4	South Australia	10
France and Colonies	125	Spain	16
Germany	193	Sweden	30
Greece	1	Switzerland	22
Great Britain	237	Tasmania	2
Guatemala	1	Turkey	4
Haiti	1	Uruguay	3
Honduras	2	Venezuela	2
Italy	58	Victoria	11

Shipments of United States Congressional publications were made on August 20, and November 23, 1894, February 18 and June 1, 1895, to the Governments of the following-named countries:

Argentina.	Colombia.	Netherlands.	South Australia.
Austria.	Denmark.	New South Wales.	Spain.
Baden.	France.	New Zealand.	Sweden.
Bavaria.	Germany.	Norway.	Switzerland.
Belgium.	England.	Peru.	Tasmania.
Buenos Ayres.	Haiti.	Portugal.	Turkey.
Brazil.	Hungary.	Prussia.	Uruguay.
Canada (Ottawa).	India.	Queensland.	Venezuela.
Canada (Toronto).	Italy.	Russia.	Victoria.
Chile.	Japan.	Saxony.	Würtemberg.

Shipments to Greece and Mexico are withheld for the present.

RECAPITULATION.

	Cases.
Total Government shipments	252
Total miscellaneous shipments	1,112
Total shipments	1,364
Total shipments last year	905
Increase over last year	459

Respectfully submitted.

W. C. Winlock,
Curator of Exchanges.

Mr. S. P. Langley,
Secretary of the Smithsonian Institution.

APPENDIX IV.

REPORT OF THE SUPERINTENDENT OF THE NATIONAL ZOOLOGICAL PARK.

SIR: I have the honor to submit the following report of the operations of the National Zoological Park for the fiscal year ending June 30, 1895.

The care of the collection of animals has engrossed most of the attention of the employees. Such small additions to the buildings and inclosures as the funds at the disposal of the park would allow have been made. Among these there may be mentioned a new inclosure for beaver, which has been established in order to give opportunity for the public to watch their building operations and to found a separate colony, and because the beaver inclosure built last year was found insufficient for the proper confinement of the animals.

It is evident that in order to maintain animals of this kind in security and safety, more room and separate paddocks are necessary. At times they fight savagely with each other, and when the inclosure is restricted even to half an acre of ground the weaker one can not save himself by flight and is frequently killed. This has happened here.

Combats also take place among the buffalo and the elk, and if a herd of these animals of any size is maintained it will be absolutely necessary to enlarge and multiply the paddocks. Great need is felt for more buffalo cows.

Disorders due to confinement have not been absent. One interesting from a scientific point of view was a spontaneous outbreak of rabies in one of the inclosures for foxes, as these animals were apparently in perfect health and the disease could not have been induced from without as far as is known. A single case at first appeared and this inoculated the entire cage, seven animals in all being lost. This curious phenomenon is of great interest as bearing upon the sporadic appearance of hydrophobia in the dog.

Careless feeding by visitors causes a great deal of trouble. Some animals habitually overeat if allowed to do so, and the food which the public tender is often unhealthful. A fine cassowary died during the year from gastric irritation due to this cause. A valuable Diana monkey was poisoned by laurel (*Kalmia latifolia*) which she snatched from the hand of a visitor, though the utmost watchfulness is exercised to keep this noxious plant from the animals.

Some very interesting additions to the collection have been made during the year. From the Yellowstone Park 20 animals were received, among them a grizzly bear weighing 730 pounds and of great ferocity, and 10 beaver. A beautiful sea lion was obtained by exchange, as well as a fine boa constrictor. A fine young puma was born, also a spotted lynx, several elk and Virginia deer, a zebu, and a llama.

The insufficient character of the buildings used for animals has been made apparent on several occasions during the year. The "animal house" was constructed with a view to the accommodation of the large carnivora and is not adapted for the proper maintenance of monkeys, tropical birds, or pachyderms. Having no other quarters, it has, however, been necessary to place under the same roof with lions and tigers, that endure moderate cold well, other creatures that need a constant temperature of 75° to 80° F. and still others (such as the rhinoceros and hippopotamus) that need still different conditions. The consequence of this is that more deaths occur than would be the case were the buildings properly arranged, and it has not been possi-

ble to prevent such accidents with the means at disposal. It is hoped that funds may be soon forthcoming for the construction of separate houses for birds and for pachyderms.

Considerable attention has been paid to the improvement of the grounds during the year. Near the eastern entrance to the park a culvert has been built to accommodate the little stream that enters here and feeds the swan pond, the opening being concealed by rockwork and shrubs so as to present the appearance of a natural spring. Below the bridge on the main road a large number of bowlders have been placed in the creek to present the appearance of a natural ledge, thus raising the water some 3 or 4 feet. This very greatly improves the stretch of water below and above the bridge and permitted the introduction of aquatic and semiaquatic plants along the edges of the stream. It has also the effect of raising the level of the water in the large pond for aquatic animals situated to the southward of the meadow.

A rustic footbridge has been thrown over the ravine that enters the park at Ontario avenue leading to the stairway by which the public pass to and from the electric-car line. The wing walls of the main bridge have been completed by the addition of rustic coping, which very much adds to the appearance of the structure. The banks of the creek above the bridge are now strengthened and protected by lining them with loose riprap and planting them with willows and other quick-growing shrubs.

The roads have also received considerable attention. The main drive to the north of the animal house has been widened to 50 feet, and greatly improved by laying a telford pavement. The main road has also been properly graded and improved between the elephant house and the buffalo house, and about 1,000 feet of it treated with macadam, making a suitable drive. Macadam has been laid on the road behind the elephant house and on the main drive from the eastern entrance to the bridge, and the large ellipse in front of the bear dens has been completed by the addition of finely pulverized stone.

The road leading into the park from Woodley road has been commenced, the work under a preliminary appropriation of $2,500 being done by the District authorities and the remainder by the park under an appropriation for $5,000. The funds on hand have been sufficient only to make a 6 per cent grade from Woodley road down to the banks of the creek. In order to make this road practicable it should be treated with macadam and a sidewalk be provided.

The water supply has been extended so as to supply the office of the park and the garden in which vegetables are raised for the animals, and additional drinking fountains have been put in. An additional sewer has been constructed, by which the toilet rooms, the elephant house, and the hippopotamus tank can discharge.

A temporary fence has been built around the pond for aquatic birds, and the fences of the buffalo and elk paddocks have been strengthened. These fences, although apparently of great strength, are found in practice to need constant watching, as the powerful attacks of these animals cause them finally to give way.

Some small plantations of shrubbery have been made from time to time as the funds at the disposal of the park would permit. These are principally in the vicinity of the buffalo and elephant houses and in parts of the park where it seemed necessary to seclude certain parts from the direct view of the public.

Animals in the collection June 30, 1895.

Name.	No.	Name.	No.
MAMMALS.		MAMMALS—continued.	
American bison (*Bison americanus*)	7	Woodchuck (*Arctomys monax*)	5
Zebu (*Bos indicus*)	3	Prairie dog (*Cynomys ludovicianus*)	25
Tora antelope (*Acelaphus tora*)	1	Red-bellied squirrel (*Sciurus aureogaster*)	1
Dorcas gazelle (*Gazella dorcas*)	1	Gray squirrel (*Sciurus carolinensis*)	20
Common goat (*Capra hircus*)	9	Fremont's chickaree (*Sciurus hudsonius fremonti*)	1
American elk (*Cervus canadensis*)	15	Crested porcupine (*Hystrix cristata*)	4
Virginia deer (*Cariacus virginianus*)	10	Canada porcupine (*Erethizon dorsatus*)	8
Mule deer (*Cariacus macrotis*)	2	Western porcupine (*Erethizon dorsatus epixanthus*)	2
Wart hog (*Phacochœrus æthiopicus*)	1	Capybara (*Hydrochœrus capybara*)	1
Peccary (*Dicotyles tajaçu*)	6	Crested agouti (*Dasyprocta cristata*)	3
Hippopotamus (*Hippopotamus amphibius*)	1	Hairy rumped agouti (*Dasyprocta prymnolopha*)	2
Sumatran rhinoceros (*Rhinoceros sumatrensis*)	1	Mexican agouti (*Dasyprocta mexicana*)	2
Llama (*Auchenia glama*)	6	Guinea pig (*Cavia porcellus*)	10
Guanaco (*Auchenia huanacos*)	1	English rabbit (*Lepus cuniculus*)	1
Indian elephant (*Elephas indicus*)	2	Peba armadillo (*Tatusia novemcincta*)	5
Lion (*Felis leo*)	4	Red kangaroo (*Macropus rufus*)	3
Tiger (*Felis tigris*)	1	Gray kangaroo (*Macropus sp.*)	5
Leopard (*Felis pardus*)	1	Common opossum (*Didelphys virginiana*)	6
Puma (*Felis concolor*)	3	BIRDS.	
Ocelot (*Felis pardalis*)	1	Golden eagle (*Aquila chrysaëtos*)	3
Bay lynx (*Lynx rufus*)	1	Bald eagle (*Haliæëtus leucocephalus*)	5
Spotted lynx (*Lynx rufus maculatus*)	4	Red-tailed hawk (*Buteo borealis*)	2
Spotted hyena (*Hyæna crocuta*)	3	Red-shouldered hawk (*Buteo lineatus*)	1
Russian wolf hound	2	Snowy owl (*Nyctea nyctea*)	1
St. Bernard dog	2	Great horned owl (*Bubo virginianus*)	11
Pointer dog	1	Yellow-and-blue macaw (*Ara araraunea*)	1
Collie dog	2	Red-and-blue macaw (*Ara chloroptera*)	1
Eskimo dog	8	Red-and-yellow-and-blue macaw (*Ara macao*)	2
Gray wolf (*Canis lupus griseo-albus*)	3	Gray parrot (*Psittacus erithacus*)	1
Black wolf (*Canis lupus griseo-albus*)	2	Yellow-naped amazon (*Amazona auropalliata*)	1
Coyote (*Canis latrans*)	4	Sulphur-crested cockatoo (*Cacatua galerita*)	1
Red fox (*Vulpes fulvus*)	6	Leadbeater's cockatoo (*Cacatua leadbeateri*)	1
Swift fox (*Vulpes velox*)	4	Bare-eyed cockatoo (*Cacatua gymnopis*)	1
Tayra (*Galictis barbara*)	1	Common crow (*Corvus americanus*)	2
Wolverine (*Gulo luscus*)	1	Raven (*Corvus corax*)	1
American badger (*Taxidea americana*)	3	Clarke's nutcracker (*Picicorvus columbianus*)	5
Kinkajou (*Cercoleptes caudivolvulus*)	1	Black-headed jay (*Cyanocitta stelleri annectens*)	1
Gray coati-mundi (*Nasua narica*)	3	Chachalaca (*Ortalis vetula maccallii*)	10
Cacomistle (*Bassaris astuta*)	2	Razor-billed curassow (*Mitua tuberosa*)	1
Raccoon (*Procyon lotor*)	18	Lesser razor-billed curassow (*Mitua tomentosa*)	1
Black bear (*Ursus americanus*)	4	Peafowl (*Pavo cristatus*)	7
Cinnamon bear (*Ursus americanus*)	2	Domestic turkey (*Meleagris gallopavo*)	1
Grizzly bear (*Ursus horribilis*)	3	Domestic fowl—black-breasted red game	2
Polar bear (*Thalassarctos maritimus*)	2	Domestic fowl—spangled Hamburg	4
California sea-lion (*Zalophus californianus*)	1	Cariama (*Cariama cristata*)	1
Sooty mangabey (*Cercocebus fuliginosus*)	1	Sand-hill crane (*Grus canadensis*)	1
Macaque monkey (*Macacus cynomolgus*)	3	Great blue heron (*Ardea herodias*)	2
Rhesus monkey (*Macacus rhesus*)	4		
Apella monkey (*Cebus apella*)	1		
White-throated capuchin (*Cebus hypoleucus*)	1		
Owl monkey (*Nyctipithecus trivirgatus*)	2		
Albino rat (*Mus rattus*)	18		
American beaver (*Castor fiber*)	9		

Animals in the collection June 30, 1895—Continued.

Name.	No.	Name.	No.
BIRDS—continued.		REPTILES—continued.	
Wood ibis (*Tantalus loculator*)	1	Gila monster (*Heloderma suspectum*)	4
Black duck (*Anas obscura*)	4	Iguana (*Iguana tuberculata*)	1
Pekin duck (*Anas* sp.)	5	Horned lizard (*Phrynosoma cornutum*)	54
Common duck (*Anas boschas*)	1	Douglass's horned lizard (*Phrynosoma douglassi*)	4
Canada goose (*Branta canadensis*)	6	Diamond rattlesnake (*Crotalus adamanteus*)	2
Chinese goose (*Anser cygnoides*)	5	Banded rattlesnake (*Crotalus horridus*)	1
Mute swan (*Cygnus gibbus*)	4	Ground rattlesnake (*Caudisona miliaris*)	1
Black swan (*Chenopis atrata*)	1	Copperhead (*Ancistrodon contortrix*)	5
European white pelican (*Pelecanus onocrotalus*)	1	Boa (*Boa constrictor*)	3
American herring gull (*Larus argentatus smithsonianus*)	1	Anaconda (*Eunectes murinus*)	1
		Bull snake (*Pityophis sayi*)	2
REPTILES.		Black snake (*Bascanium constrictor*)	5
		Garter snake (*Eutænia sirtalis*)	4
Alligator (*Alligator mississippiensis*)	16	Water snake (*Natrix sipedon*)	12
Snapping turtle (*Chelydra serpentina*)	2	King snake (*Ophibolus doliatus*)	1

	Indigenous.	Foreign.	Domesticated.	Total.
Mammals	197	49	56	302
Birds	58	13	29	100
Reptiles	115	3		118
Total	370	65	85	520

This total of 520 may be divided into two classes with regard to size:

	Mammals.	Birds.	Reptiles.	Total.
Larger animals	140	51	14	205
Smaller animals	162	49	104	315
Total	302	100	118	520

List of accessions.

ANIMALS PRESENTED.

Name.	Donor.	Number of specimens.
Sooty mangabey	C. O. Chenault, New Orleans, La.	1
Apella	F. H. Mattern, Washington, D. C.	1
Leopard	R. Dorsey Mohun, Washington, D. C.	1
Bay lynx	H. R. Case, Frederick, Md.	1
Spotted lynx	F. Hardman, San Antonio, Tex.	2
Gray wolf	S. H. Stephens & Co., Pueblo, Colo.	3
Pointer dog	F. C. Graves, Washington, D. C.	1
St. Bernard dog	T. Wasserbach, Washington, D. C.	1
Collie dog	G. Brown Goode, Washington, D. C.	2
Eskimo dog	Mrs. R. E. Peary, Washington, D. C.	3
Red fox	Harry Mauger, Washington, D. C.	1

List of accessions—Continued.

ANIMALS PRESENTED—Continued.

Name.	Donor.	Number of specimens.
Red fox	J. H. Morlan, Redcross, Ind	1
Do	Dr. Robinson, Washington, D. C	1
Gray fox	J. H. Morlan. Redcross, Ind	2
Tayra	Hon. Wm. McAdoo, Washington, D. C	1
Cacomistle	F. Hardman. San Antonio, Tex	1
Gray coati-mundi	C. O. Chenault, New Orleans, La	1
Raccoon	J. H. Morlan, Redcross, Ind	3
Do	J. J. Prather, Washington, D. C	1
Do	Mrs. Worshain, Washington, D. C	1
Do	W. E. Tribbett, Riverside, Va	3
Black bear	Mrs. M. B. Duryea, Aiken, S. C	1
Common goat	Mrs. L. G. Freewalt, Washington, D. C	1
Dorcas gazelle	C. O. Chenault, New Orleans, La	3
Virginia deer	do	2
Peccary	Col. Anson Mills, U. S. A., Washington, D. C	4
Woodchuck	J. H. Morlan, Redcross, Ind	2
Do	F. Hertzog, Washington, D. C	1
Do	H. K. Mannafee, Kensington, Md	1
Woodchuck (albino)	D. M. Clark, Lacona, N. Y	1
Red-bellied squirrel	C. O. Chenault, New Orleans, La	2
Gray squirrel	(No data)	1
Flying squirrel	Mr. Wooldridge, Washington, D. C	1
Canada porcupine	Frank Rich, Bethel, Me	6
Mexican agouti	C. O. Chenault, New Orleans, La	2
Black rabbit	Miss M. M. North, Anacostia, D. C	1
Nine-banded armadillo	Col. Anson Mills, U. S. A., Washington, D. C	6
Do	F. Hardman, San Antonio, Tex	5
Opossum	Hudson Bay Fur Company, Washington, D. C	1
Do	F. F. Fitzhugh, Washington, D. C	1
Golden eagle	G. B. Gainer, Gallatin, Tenn	1
Do	Chaplin Perkins, Washington, D. C	1
Bald eagle	Fritz Reuter, Washington, D. C	1
Red-tailed hawk	H. D. Renninger, Clifton Beach, Md	1
Do	Mr. Lees, Washington, D. C	1
Red shouldered hawk	W. P. Lawrence, Norfolk, Conn	1
Do	Bernard Balluff, Washington, D. C	1
American osprey	H. R. Jehle, Montclair, N. J	2
Great horned owl	Frank Stump, Washington, D. C	1
Do	Miss Edmonia Edwards	2
Do	Dr. R. A. Bates, Washington, D. C	1
Chachalaca	Col. Anson Mills U. S. A., Washington, D. C	10
Turkey	Mrs. Katharine Ensworth, Washington, D. C	1
Great blue heron	Perrie and Britt, Washington, D. C	1
Do	A. M. Nicholson, Orlando, Fla	3
Wood ibis	do	2
Alligator	Col. Max Meyerson, Florida	2
Do	Elmer C. Wood, Washington, D. C	1
Do	Miss Cox, Washington, D. C	1
Do	Emery Cox, Brightwood, D. C	1
Do	Hon. J. D. Cameron, Washington, D. C	2
Do	Mrs. Atchinson, Washington, D. C	1
Snapping turtle	Fred. Cowett, Washington, D. C	1
Do	W. Willfield, Georgiana, Fla	1

List of accessions—Continued.

ANIMALS PRESENTED—Continued.

Name.	Donor.	Number of specimens.
Iguana	C. O Chenault, New Orleans, La	1
Gila Monster	Miss Lydia L. Hunt, San Carlos Ariz	2
Horned lizard	do	3
Do	F. Hardman, San Antonio Tex	55
Banded rattlesnake	A E McConnell, Washington D. C	1
Do	C. O Mills, Washington, D C	1
Do	E. Jones and G. L. Edmunds, Ralston, Pa	1
Milk snake	Mr. Shaw, Washington, D. C	1
Pine snake	L. N. O'Dell, Washington D. C	1
Black snake	W. S. Heath, Washington, D C	1
Garter snake	W. V. Cox, Brightwood, D. C	1
Do	Emery Cox, Brightwood, D. C	1
Water snake	F. Watrous, Washington, D. C	1
Do	W. C. Weeden, Washington, D. C	1
Do	C. A. Cooper, Washington, D. C	1
Hog-nose snake	W. W. Worthington, Florence, Ky	1

ANIMALS LENT.

Grivet	Schuyler Crosby, Boston, Mass	1
Macaque	J. M. Mason, Charlestown, W. Va	1
White-throated cebus	Mrs. W. C. Ames, Washington, D. C	1
Black ateles	Mrs. E. Byles, Washington, D. C	1
Lion	Adam Forepaugh shows	2
Spotted hyena	do	3
Tora antelope	do	1
Wart hog	do	1
European porcupine	do	1
Red kangaroo	do	3
Gray kangaroo	do	2
Gray parrot	Mrs. Milliken, Washington, D. C	1
Blue-fronted amazon	Mrs. L. Hopfenmaier, Washington, D. C	1
Yellow-naped amazon	Mrs. A. B. Williams, Washington, D. C	1

ANIMALS RECEIVED IN EXCHANGE.

Rhesus	E. S. Schmid, Washington, D. C	3
Raccoon	do	1
California sea-lion	John Lesner, Norfolk, Va	1
Virginia deer	Thomas Blagden, Washington, D. C	1
Gray squirrel	W. F. McClure, Washington, D. C	2
Banded rattlesnake	L. N. O'Dell, Washington, D. C	1
Boa constrictor	E. S. Schmid, Washington, D. C	1

Animals born in the National Zoological Park.

Puma (*Felis concolor*)	2
Spotted lynx (*Lynx rufus maculatus*)	1
Raccoon (*Procyon lotor*)	5
Zebu (*Bos indicus*)	1
American elk (*Cervus canadensis*)	2
Virginia deer (*Cariacus virginianus*)	7
Llama (*Auchenia glama*)	1
Canada porcupine (*Erethizon dorsatus*)	2

Animals captured in the National Zoological Park.

Gray squirrel (*Sciurus carolinensis*)	1
Opossum (*Didelphys virginiana*)	3
Black snake (*Bascanium constrictor*)	1

Animals collected in the Yellowstone National Park.

Grizzly bear (*Ursus horribilis*)	1
American beaver (*Castor fiber*)	10
Clarke's nutcracker (*Picicorvus columbianus*)	7
Black-headed jay (*Cyanocitta stelleri annectens*)	1
Hutchins goose (*Branta canadensis hutchinsii*)	1

SUMMARY OF ACCESSIONS.

Animals presented		187
Animals lent		20
Animals received in exchange		10
Animals born in the Zoological Park		21
Animals captured in the Zoological Park		5
Animals received from the Yellowstone National Park		20
Total		263
Number of specimens on hand June 30, 1894		510
Accessions during the year ending June 30, 1895		263
Total		773
Deduct—		
Deaths	204	
Animals escaped or liberated	11	
Animals exchanged	13	
Animals returned to owners	25	
		253
Animals on hand June 30, 1895		520

Respectfully submitted.

FRANK BAKER,
Superintendent.

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Appendix V.

REPORT ON THE WORK OF THE ASTRO-PHYSICAL OBSERVATORY FOR THE YEAR ENDING JUNE 30, 1895.

During the past fiscal year the work of the Astro-physical Observatory has continued to be the investigation of the infra-red solar spectrum by the bolometric method, fully described in the report of the observatory for 1893.

This work consists, briefly, in the production of curves, automatically traced on a photographic plate by means of the bolometer and its attendant apparatus, which record by their deflections the existence, position, and intensity of (invisible) absorption lines in the infra-red spectrum from a prism of rock salt or from a grating.

Such a curve, ideally perfect, would show every line in the spectrum as a deflection of the curve in its proper place on the plate, and there would be no deflection present not due to such a solar line. A curve which fulfills the first condition as regards every considerable line, is in substance already at hand, and has been shown even in a former stage of the work, and it is in fact easily obtained at any time by the present method, so long as we confine our attention to the principal newly discovered lines; lines or deflections, that is, which are due to solar and telluric causes. (These may be called "true" lines as distinguished from the smaller "false" lines due to minute local disturbance.) I say the principal lines, because those first discovered result from deflections whose amount is relatively considerable as compared with accidental local disturbances, and in this case the true lines are distinguishable (if only by their size and prominence) from the false ones, the latter being due to many causes, which all, however, tend to produce more or less minute deflections. This minuteness, then, fortunately, is one of the characteristics of the false lines. Now, though these minor accidental deflections are negligible compared with the more prominent real ones, yet as the work progresses and still finer and finer details are sought, we must evidently at last reach a condition where, having discovered all the larger true lines, we in seeking smaller and smaller ones, finally come to such minute deflections that these, though constant, are reduced to the same order of magnitude as the accidental or "false" ones, however minute the latter may be.

(In this connection it is proper to state that the plate of the spectrum showing very minute detail, published in January of this year, had already been given in illustration of the process and printed in the Proceedings of the British Association for the Advancement of Science, for August, 1894, accompanied by the statement that it was presented "only in illustration," and was "not to be treated as a criterion of the final results," and that the statement that all these lines had then been verified escaped attention.)

It is again fortunate, that our criterion is not that of size alone, but that in order to distinguish between true deflections, however minute (due to solar and telluric causes), and minute "false" deflections of the same order of size due to accidental disturbances, an independent, simple, and infallible criterion exists—infallible, that is, in theory, but not always easy in practical application.

This criterion has been elsewhere mentioned, and indeed is sufficiently obvious to need little explanation; for if among a large number of curves representing the same spectral region a deflection asserts itself constantly at the same place, that deflection is evidently due to a constant cause and not to an accidental one. Now, from the nature of the process, it is hardly possible to imagine any efficient constant cause of such minute abrupt deflections as are in question, which is not a solar or telluric cause, and it is these only we seek. Again, it will be seen that, provided the deflections are of a finite order of minuteness, and that our mechanism can record with such precision that the true or solar line falls at absolutely the same place on each of even two plates, the chances are infinite against any exact coincidence of lines which are not "true." In practice, where absolute accuracy is unattainable, we must determine experimentally between what limits error customarily presents itself, in the case of the true lines and in that of the false, and then ascertain what probable error attaches to the result from the final comparison of any number.

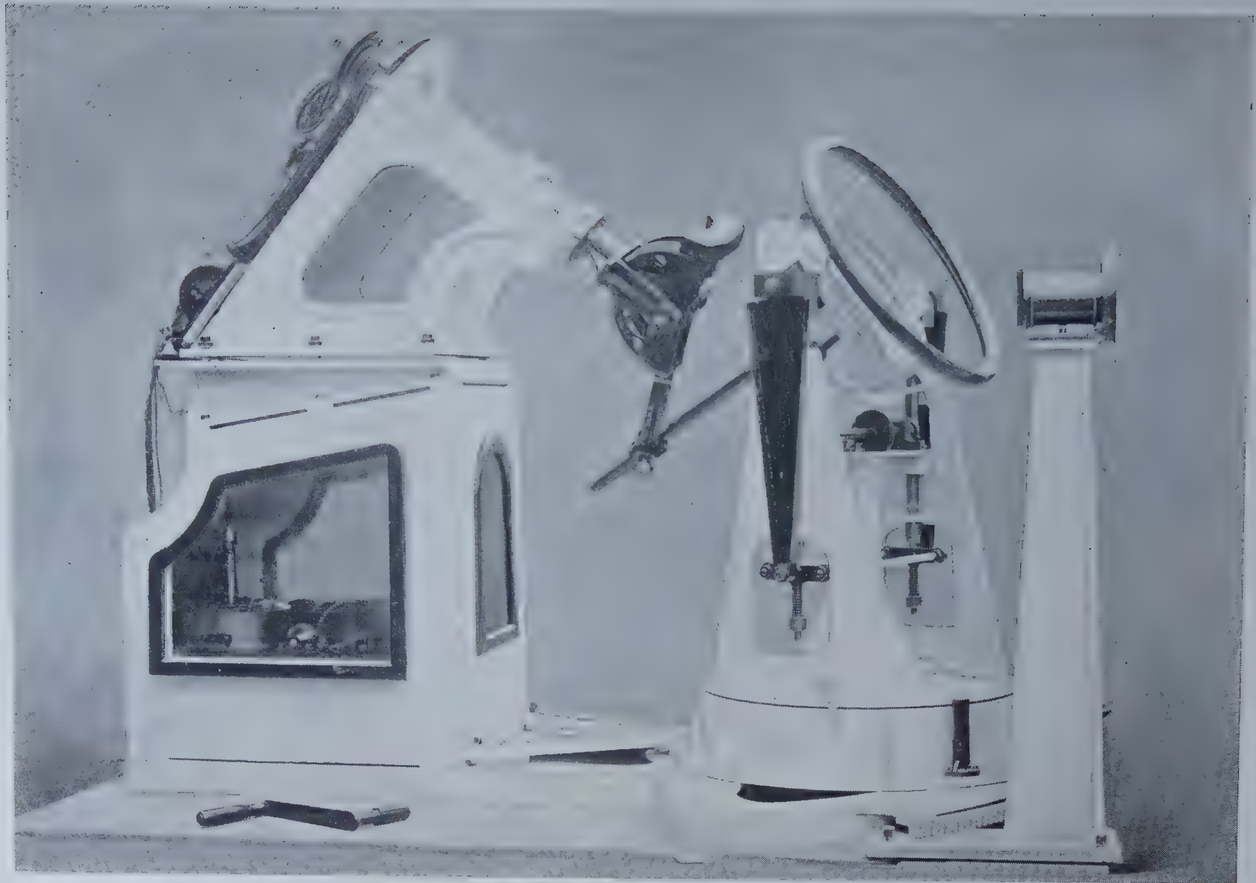
During the preceding year certain main deflections, somewhat less than one hundred in number, were so established as "true;" but when within the past year the work reached a state of progress warranting the more detailed investigation of the spectrum alluded to, upon applying the criterion mentioned above to the deflections representing the minute lines with which the work was now dealing, it became evident that the number of very small casual deflections made it desirable to subject the method of making the curves to a renewed examination, in which the source of each class of minute error should be as far as possible discriminated. This examination has shown that the site which the observatory occupies is exposed to local tremors and magnetic disturbances in a still greater degree than had been anticipated. The appended table gives a rough classification of the sources of these errors.

Classification of errors affecting bolographs.

Kind of error.	Causes.	Remarks.
(1) In the position of a line...	Variation of temperature of the prism, inaccurate clockwork, etc.	Mostly due to temperature conditions, the direct result of the present building.
(2) The suppression of small true lines.	Inaccuracy in photographic reduction to line spectra.	
(3) The production of false small lines.	Earth tremors, magnetic fluctuations, thermal currents in bolometer circuit, change of potential in batteries.	Due (1) to location of building; (2) to avoidable instrumental defects.

From what has been said it will be seen that in order that the agreement of a number of separate curves might furnish conclusive evidence of the reality of a line, it became necessary to establish experimentally the amount of accidental deflection due to local tremor wholly, and also the admissible amount of final error inherent in the mechanical, optical, and photographic processes employed. The following degree of accuracy has been judged possible as a final attainment with the present means, and is that aimed at, although not yet reached. This aim is to produce curves which, in a length of 60 centimeters, shall be free from any probable error of a magnitude greater than one-tenth of a millimeter—a quantity whose minuteness relative to the means employed may be understood when it is mentioned that it corresponds to six-tenths of a second of arc, as measured on the circle of the spectrometer.

For the above reasons it will be seen that the improvement of the apparatus used, as well as the investigation of sources of possible error, became the most important work of the observatory before the publication of authoritative results.



THE SIDEROSTAT OF THE ASTROPHYSICAL OBSERVATORY.

I am pleased to state that by the use of the improved apparatus, to which I refer later, the amount of the probable error has been greatly reduced, and the investigation of the causes of false deflections has justified the belief that those not directly due to the site of the observatory will be, ere long, eliminated.

During the progress of this work the making of observations with the apparatus on hand has not been suspended, but, on the contrary, has produced a larger number of bolographs than during any preceding year. The work in detail may most conveniently be classified under three general heads:

A. General spectro-bolographic work.

B. Special spectro-bolographic work.

C. Improvements in apparatus and methods.

A. The subjoined table shows in detail the number of working days and the number of bolographs made in the observatory during the year.

I.

Date.	Days available.	Bolographs of spectra.	Experimental bolographs.	Remarks.
1894.				
July	4	5	....	Improving apparatus.
August	....	....	....	Main observatory closed twenty-one days.
September	5	12	....	
October	9	19	1	
November	4	9	....	
December	12	33	2	
1895.				
January	7	20	1	
February	8	24	....	
March	3	10	....	Constructing new piers.
April	8	42	1	
May	12	44	20	
June	5	14	4	Unusually bad weather.
	77	232	29	
		29		
Total	....	261		

On the 5th of December, 1894, an extended experimental investigation of the errors exhibited by the apparatus and the methods in use was begun on a scale not before tried, and the effects from variations in the potentials of the batteries and from temperature effects in the complicated circuit of the bolometer, as well as from the tremors of the earth and changes of the magnetic field, incident to the bad location of the observatory, were found to be larger than had been assumed from previous trial. Since that time the reduction of these errors has been the constant effort of the observatory.

The entire circuit of the bolometer has been overhauled and made to consist, as nearly as possible, of copper of the same density and without joints which might produce thermal effects.

The experimental bolographs, referred to in the above table, were, for the most part, devoted to the investigation of the error produced by minute variations in the potentials of the batteries used in the bolometer circuit. In order to give some idea of the delicacy of the performance required of this apparatus, it may be added that the variations averaged only 0.0000007 of a volt, but were still considered to be too large for accurate working. It has also become evident that the arrangement of balancing coils, which have up to the present time been of the usual laboratory type, were capable of producing, under the fluctuations of temperature in the observatory, effects of the magnitude of those produced by the minute solar lines, which it was now being attempted to define and measure.

The greater number of working days have been devoted to the production of a large number of bolographs of the upper infra-red spectrum made under widely varying conditions for the purpose of studying the possible causes of the errors which have been roughly indicated above. To this end an investigation of the personalities of different observers, as they may affect the final results of each observation, has also been undertaken.

B. The classification, detailed examination, and final reduction of bolographs to the linear translations, or "cylindrics," which resemble in appearance photographs of the visible spectrum, has kept pace with the production of the most satisfactory curves.

The production of these linear spectra involves the services of a photographer during three to five days in each instance, and extreme accuracy; for this reason, only the best of the curves obtained are subjected to this process. The table given below includes only those plates which are free from defects, and consequently represents but a small part of the labor involved in the production of results which may seem intrinsically small:

II.

Linear translations made (plates 10 × 30 cm.).

Bolographs of infra-red spectrum from—	Number of cylindrics made.	Cylindric negatives.	Composites.
α to $\rho\sigma\tau$	17	8	5
$\rho\sigma\tau$ to Ω	18	8	2
Ω to 4.$^{\mu}$5	7	4	0
ψ to χ	13	6	4
Total	55	26	11

The following table shows the number of plates developed:

III.

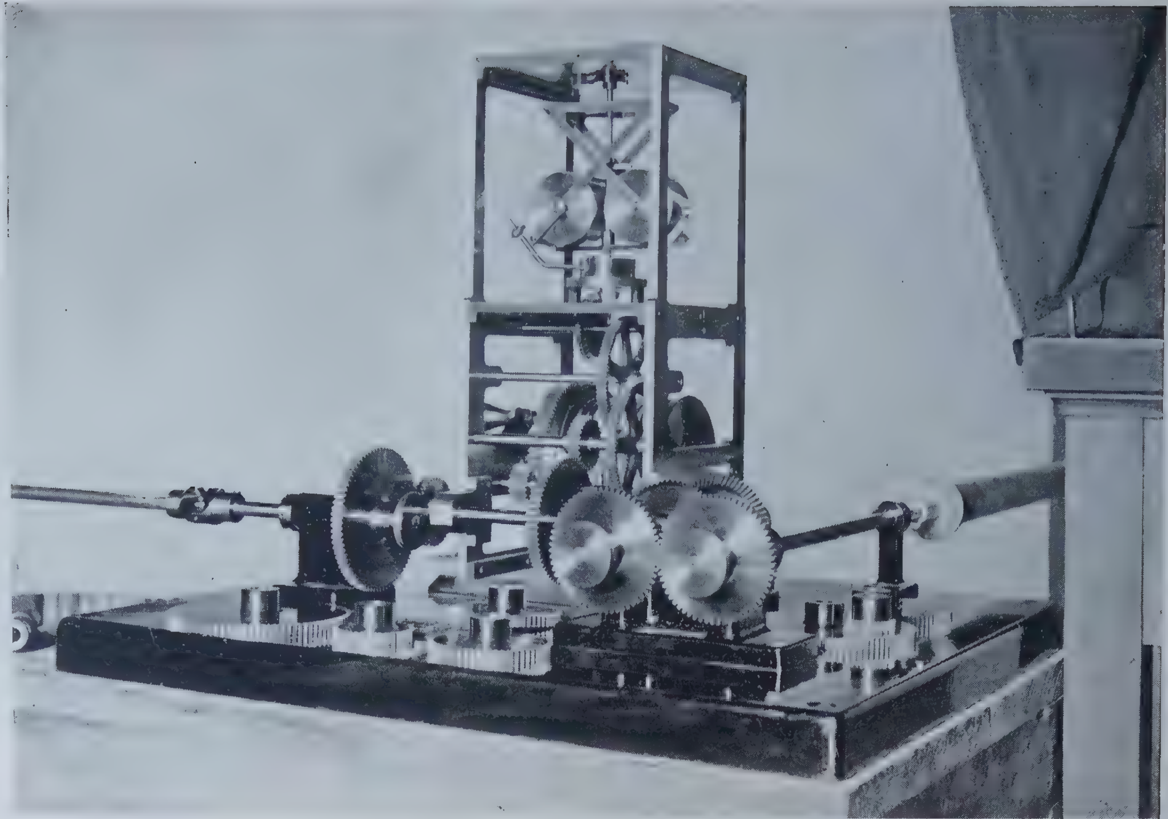
Whole number of plates developed.

	1894.						1895.					
	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.
For linear translations	42	8	20	16	21	5	3	8	11	0	7	9
Bolographs	5	0	12	20	9	35	21	24	10	43	45	13
Other photographs	31	0	0	5	3	10	0	0	38	11	0	2

C. The development of the instruments used, to as near mechanical perfection as it is possible to obtain with the means at command and under the conditions prevailing in the observatory, has constituted, for the reasons given above, a very large part of the work up to the present time.

The siderostat has been furnished with a new counterpoise for the altazimuth mirror support, a new direction axis and base for the mirror, and a new polar axis, resting upon ball bearings, completed December 1, 1894. This massive instrument, which has been greatly modified since it left the maker's hands until it has taken the form shown in the annexed illustration, is now capable of being brought to exact adjustment, and needs only the addition of a new governor for its driving clock to make it most efficient.

With the hope of compensating in some degree for the extreme variations of temperature due to the construction of the present building, a conduit for warm air in winter and cold air in summer from the blowers in the Smithsonian building was constructed. The coils of piping for bringing the admitted air to the proper temperature after it has reached the observatory are not yet complete, and the need of



THE DRIVING CLOCK OF THE SPECTRO-BOLOMETER.

a more perfect automatic regulation of the temperature (in the interest of the work rather than of the comfort of the observer) is being provided for.

During the year 1893 the galvanometer, perhaps the most important part of the train of apparatus, was brought to such a condition that no further improvement in this direction was regarded as necessary until justified by a more permanent building and better facilities for isolation from magnetic and seismic disturbances than are at present capable of being obtained, but in order to make the best use of the facilities at hand, the former unstable galvanometer pier has been replaced by a massive brick and stone structure, finished March 23, 1895, built in such a manner that protection from the vibrations of the surface earth is insured. It is, however, proper to repeat that the vibrations of the earth, as well as the seismic disturbances, consequent to the location of the observatory amid the traffic of the city, continue to present serious causes of error which no possible care or pains seems able to prevent.

By examinations conducted in October, 1894, it was shown that the driving clock of the spectro-bolometer train performed its part with less than the rigorous accuracy required. It has consequently been replaced by a much more accurate mechanism, of which an illustration is given, installed April 2, 1895, which was constructed by Messrs. Warner & Swasey, of Cleveland, in part, and in part by Mr. John A. Brashear, of Allegheny. This clock which controls both the movement of the photographic plate and of the great azimuth circle carrying the prism, has been shown, under the strain of repeated use, to perform its duty within the limit of allowed probable error—that is, one-tenth of a millimeter in 60 centimeters motion of the plate, or six-tenths of a second of arc in one degree at the circle. A new pier has also been constructed for the support of this clock.

A mean solar standard clock, by the Howard Watch and Clock Company, has been placed in the basement of the Smithsonian Institution.

Great difficulty has always been experienced in the proper protection and preservation of the optical surfaces of the rock salt necessarily employed. A large gain in time and economy has been made by introducing the practice of repolishing the surfaces in the observatory itself, and it is now possible to refigure the surface of a large prism or lens in a few hours, at a small cost, where it was formerly the custom to send such a prism or lens to distant opticians at a considerable expense of time and money.

A new bolometer case, with provision for receiving radiations from two sources, and many minor pieces of apparatus, have been constructed in the workshop of the observatory. These improvements in the apparatus have been accompanied by improvements in the method of their use, which will more fittingly form the subject of future report, but they may nearly all be connected with the need of a more constant temperature, combined with freedom from ground and magnetic tremors.

MINOR WORK OF THE YEAR.

Some further experimental data were collected for the more accurate determination of the laws governing the change of the index of refraction of rock salt, with changes in its temperature. The approach of observing weather prevented the completion of the experiments.

All of the bolometers on hand have been calibrated, in order that their relative efficiencies, as well as the means of reading their indications quantitatively, might be known.

The very minute and rapid changes in the potential of certain types of storage batteries, intended for the use with the bolometer, have been measured, and their effect upon the indications of the bolometer investigated.

It should finally be repeated, as the most important conclusion of the year, that the final degree of precision attainable can never be reached in the present site.

PERSONNEL.

Mr. C. G. Abbot was appointed as assistant in the observatory on the 19th of June, 1895.

APPENDIX VI.

REPORT OF THE LIBRARIAN.

SIR: I have the honor to present herewith a report upon the operations of the library of the Smithsonian Institution during the fiscal year ending June 30, 1895.

The entry numbers of accessions to the Smithsonian deposit at the Library of Congress extend from 292,426 to 314,499.

The following table gives an analysis in volumes, parts of volumes, pamphlets, and charts of the accessions during the year:

Publications received between July 1, 1894, and June 30, 1895.

	Quarto or larger.	Octavo or smaller.	Total.
Volumes	408	1,154	1,562
Parts of volumes	15,842	8,422	24,264
Pamphlets	451	3,028	3,479
Charts			332
Total			29,637

In addition to this there have been added to the Secretary's library, office library, and the library of the Astrophysical Observatory 321 volumes and pamphlets and 1,995 parts of volumes, making a total of 2,316, and a grand total of accessions for the year of 31,953 volumes, parts of volumes, pamphlets, and charts.

Of these accessions, 133 volumes, 7,451 parts of volumes, and 619 pamphlets were retained for the use of the United States National Museum, and 1,176 medical dissertations were deposited in the library of the Surgeon-General, United States Army; the remaining publications were sent to the Library of Congress on the Monday after their receipt.

In carrying out the plan formulated by the Secretary in 1887 for increasing the library exchanges, 473 letters were written asking for publications not on the list, or for numbers to complete the series already in the library. I am enabled to report that 182 new exchanges have been thereby secured, and that 97 defective series were either completed or added to, as far as the publishers were able to supply the missing parts.

A separate record of periodicals received is kept, and from this it appears that the library is now currently receiving 3,045 periodicals, magazines, and publications of learned societies. This number does not, however, include all such publications arriving at the Institution, inasmuch as many societies whose publications are issued irregularly had not been included in the periodical record up to within recent times. A detailed statement of the language and frequency of issue of these publications is herewith given, roughly divided into pure science, of which there are 1,565, applied science 704, and miscellaneous 776.

PURE SCIENCE.

	Annual.	Quarterly.	Monthly.	Fortnightly.	Weekly.	Daily.	Irregular.	Total.
English	124	98	95	10	5	1	199	532
German	135	54	40	11	6		112	358
French	107	66	32	15	5	1	82	328
Italian	37	19	19	3	1		18	97
Spanish	15	8	16	1			15	55
Russian	9	9	5	1			28	52
Dutch	8	5	4				12	29
Swedish	10	3	2				11	26
Hungarian	2	6	4				14	26
Portuguese	1	1	1				15	18
Danish	3	4	1				5	13
Norwegian	3	4					3	10
Finnish	2	1	1				3	7
Roumanian	2		1				1	4
Modern Greek	1	1		1				3
Japanese			2				1	3
Bohemian	1	1	1					3
Arabic			1					1

APPLIED SCIENCE.

English	82	30	114	17	52		79	314
German	54	15	28	13	16		33	159
French	25	13	50	8	10		17	123
Spanish	4	5	10	5	3		10	37
Italian	5	6	10	1			6	28
Russian	2	1	5	2			5	15
Dutch	1	4	1				2	8
Swedish	3	2					1	6
Finnish	2		1				1	4
Portuguese			2	1				3
Norwegian	1		2					3
Danish	3							3
Japanese			1					1

MISCELLANEOUS.

English	107	30	154	16	91		128	526
German	47	5	15	5	5		27	104
French	10	5	14	9	11		23	72
Spanish	5		3	4	1		8	21
Italian	4		6	2			7	19
Dutch	4		1		3		1	9
Swedish				2			3	5
Norwegian	2				1		2	5
Danish	2						1	3
Hungarian	1		1				1	3
Russian	1						2	3
Servian		1	1				1	3
Volapük			1				1	2
Portuguese							1	1

The following universities have sent complete sets of their academic publications, including inaugural dissertations:

Basel,
Berlin,
Bern,
Bonn,
Breslau,
Erlangen,
Freiburg,
Giessen,
Greifswald,
Halle-Wurtem,
Heidelburg,
Helsingfors,
Jena,
Johns Hopkins,
Kiel,
Königsberg,
Leipzig,
Louvain,
Lund,
Marburg,
Tubingen,
Utretcht,
Würzburg,
Zurich.

Of late a considerable number of American universities have begun to publisn dissertations accepted for the degree of doctor of philosophy, and correspondence is now in progress for the purpose of securing full sets of these for the Library.

For some time the question of providing reading matter for the employees of the Institution has been under consideration. During the year the Secretary authorized the purchase and binding of sets of a number of the more important literary magazines. These magazines, which are freely used, are also of much value in a scientific library, as they often contain early reports of explorations, new discoveries, and inventions.

Through a course of changes in the Smithsonian Building, much needed improvements in the ventilation and lighting of the reading room and library offices were rendered possible.

The list of donors to the library has become so large that it is impossible to specify them. Attention, however, must be directed to a magnificent gift of His Imperial Majesty the Sultan of Turkey of more than fifty volumes of photographs representing the present condition of the Ottoman Empire in all departments of industry, learning, and art. The Institution has also acquired the library of the late Robert Stanton Avery by bequest.

In addition to the reading room, which contains the current periodicals and transactions of learned societies, a room is provided for works of reference, and sectional libraries relating to astronomy and aerodromics are maintained. A collection of books and catalogues containing addresses is deposited in the office of the Bureau of International Exchanges.

The library has now set apart five communicating rooms on the north side of the first floor, as well as a room on the second floor of the building, for prints. In addition to these, the various sectional libraries above referred to are kept in the different office rooms. The space assigned is more than double that allowed in past years, and the facilities thus accorded are much appreciated by the staff of the Institution and of the various scientific bureaus of the Government in Washington.

By your direction I spent the months of August and September, 1894, in England and on the Continent of Europe, in examining into the exchange service. I also visited a number of libraries and booksellers and secured information concerning the indexing of scientific literature. A detailed report upon these subjects has already been presented to you.

Respectfully submitted.

CYRUS ADLER, *Librarian.*

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

Appendix VII.

REPORT OF THE EDITOR FOR THE YEAR ENDING JUNE 30, 1895.

Sir: I have the honor to submit the following report on the publications of the Smithsonian Institution for the year ending June 30, 1895:

I. SMITHSONIAN CONTRIBUTIONS TO KNOWLEDGE.

The first memoir of the Contributions to Knowledge was by Messrs. Squier and Davis, on Ancient Monuments of the Mississippi Valley, published in 1848; since which time 127 memoirs, pertaining to nearly all branches of knowledge, have been issued, making twenty-seven completed quarto volumes.

Parts of two other volumes have been printed and three additional volumes are now in press.

No memoirs of this series were published during the year, though the manuscript of two papers was sent to the printer, one by Prof. E. W. Morley, on Densities of Oxygen and Hydrogen, and one by Drs. Billings, Mitchell, and Bergey, on the Composition of Expired Air and its Effects on Animal Life.

II. SMITHSONIAN MISCELLANEOUS COLLECTIONS.

The first volume of the series of Miscellaneous Collections was published in 1862, and the series now numbers 35 completed octavo volumes, embracing 167 distinct papers, besides parts of 3 additional volumes.

The following papers of this series were published during the past fiscal year:

No. 854. Smithsonian Geographical Tables, prepared by R. S. Woodward. (Part of Vol. XXXV of the Smithsonian Miscellaneous Collections.) Octavo, cv + 182 pages. The other parts of Vol. XXXV are the Meteorological Tables, issued in 1893, and the Physical Tables, now in press.

No. 969. The Varieties of the Human Species. Principles and Methods of Classification. By Giuseppe Sergi. (Part of Vol. XXXVIII of the Smithsonian Miscellaneous Collections.) Octavo pamphlet of 61 pages; illustrated with 50 text figures.

No 970. Bibliography of Aceto Acetic Ester, by Paul H. Seymour, M. S. (Part of Vol. XXXVIII of the Smithsonian Miscellaneous Collections.) Octavo pamphle, of x + 148 pages.

No. 971. Indexes to the Literatures of Cerium and Lanthanum, by W. H. Magee, Ph. D. (Part of Vol. XXXVIII of the Smithsonian Miscellaneous Collections.) Octavo pamphlet of 43 pages.

No. 972. Index to the Literature of Didymium, 1842–1893, by A. C. Langmuir, Ph. D. (Part of Vol. XXXVIII of the Smithsonian Miscellaneous Collections.) Octavo pamphlet of 20 pages.

No. 975. Diary of a Journey through Mongolia and Tibet in 1891 and 1892, by William Woodville Rockhill. Octavo, xx + 413 pages; illustrated with 13 text figures, 28 plates, and large map.

SEPARATES FROM ANNUAL REPORT.

No. 926. Proceedings of the Board of Regents and Report of the Executive Committee for the year ending June 30, 1893, together with Acts of Congress. (From the Smithsonian Report for 1893.) Octavo pamphlet of 33 pages.

No. 927. The Wanderings of the North Pole, by Sir Robert Ball, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 13 pages.

No. 928. The Great Lunar Crator Tycho, by A. C. Ranyard. (From the Smithsonian Report for 1893.) Octavo pamphlet of 6 pages.

No. 929. The Early Temple and Pyramid Builders, by J. Norman Lockyer. (From the Smithsonian Report for 1893.) Octavo pamphlet of 11 pages.

No. 930. Variable Stars, by Prof. C. A. Young. (From the Smithsonian Report for 1893.) Octavo pamphlet of 5 pages.

No. 931. The Luminiferous Æther, by Sir George G. Stokes. (From the Smithsonian Report for 1893.) Octavo pamphlet of 7 pages.

No. 932. Atoms and Sunbeams, by Sir Robert Ball, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 13 pages.

No. 933. Fundamental Units of Measure, by T. C. Mendenhall. (From the Smithsonian Report for 1893.) Octavo pamphlet of 15 pages.

No. 934. Photography in the Colors of Nature, by F. E. Ives. (From the Smithsonian Report for 1893.) Octavo pamphlet of 12 pages.

No. 935. Photographs in Natural Colors, by the Process of L. Lumbirèe, by Leon Warnerke. (From the Smithsonian Report for 1893.) Octavo pamphlet of 2 pages.

No. 936. Electric-Spark Photographs of Flying Bullets, by C. V. Boys, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 18 pages; illustrated with 11 plates.

No. 937. Magnetic Properties of Liquid Oxygen, by Prof. James Dewar, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 5 pages; illustrated with 1 figure.

No. 937. The Problem of Flying, by Otto Lilienthal. (From the Smithsonian Report for 1893.) Octavo pamphlet of 6 pages; illustrated with 6 figures.

No. 938. Practical Experiments in Soaring, by Otto Lilienthal. (From the Smithsonian Report for 1893.) Octavo pamphlet of 5 pages; illustrated with 2 plates.

No. 939. Phenomena Connected with Cloudy Condensation, by John Aitken, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 30 pages.

No. 940. On Chemical Energy, by Dr. W. Ostwald. (From the Smithsonian Report for 1893.) Octavo pamphlet of 8 pages.

No. 941. The American Chemist, by Prof. G. C. Caldwell. (From the Smithsonian Report for 1893.) Octavo pamphlet of 14 pages.

No. 942. The Highest Meteorological Station in the World, by A. Lawrence Rotch. (From the Smithsonian Report for 1893.) Octavo pamphlet of 5 pages.

No. 943. The Mont Blanc Observatory. (From the Smithsonian Report for 1893.) Octavo pamphlet of 5 pages; illustrated with 1 figure.

No. 944. Relations of Air and Water to Temperature and Life, by Gardiner G. Hubbard. (From the Smithsonian Report for 1893.) Octavo pamphlet of 11 pages.

No. 945. The Ice Age and its Work, by A. R. Wallace, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 24 pages; illustrated with 1 plate.

No. 946. Geologic Time, as indicated by the Sedimentary Rocks of North America, by Charles D. Walcott. (From the Smithsonian Report for 1893.) Octavo pamphlet of 34 pages; illustrated with 1 map.

No. 947. The Age of the Earth, by Clarence King. (From the Smithsonian Report for 1893.) Octavo pamphlet of 18 pages; illustrated with 2 plates and 1 figure.

No. 948. The Renewal of Antarctic Exploration, by John Murray, LL. D. (From the Smithsonian Report for 1893.) Octavo pamphlet of 21 pages; illustrated with 1 map.

No. 949. The North Polar Basin, by Henry Seebohm, F. L. S., F. Z. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 20 pages; illustrated with 1 map.

No. 950. The Present Standpoint of Geography, by Clements R. Markham, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 24 pages.

No. 951. How Maps are Made, by W. B. Blakie. (From the Smithsonian Report for 1893.) Octavo pamphlet of 15 pages; illustrated with 2 plates.

No. 952. Biology in Relation to other Natural Sciences, by J. S. Burdon-Sanderson, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 29 pages.

No. 953. Field Study in Ornithology, by H. B. Tristram, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 21 pages.

No. 954. The so-called Bugonia of the Ancients, and its Relation to a bee-like Fly—Eristalis tenax, by C. R. Osten-Sacken. (From the Smithsonian Report for 1893.) Octavo pamphlet of 14 pages.

No. 955. Comparative Locomotion of Different Animals, by E. J. Marey. (From the Smithsonian Report for 1893.) Octavo pamphlet of 4 pages; illustrated with 3 plates.

No. 956. The Marine Biological Stations of Europe, by Bashford Dean. (From the Smithsonian Report for 1893.) Octavo pamphlet of 15 pages; illustrated with 2 figures and 9 plates.

No. 957. The Air and Life, by Henry de Varigny. (From the Smithsonian Report for 1893.) Octavo pamphlet of 24 pages.

No. 958. Deep-sea Deposits, by A. Daubrée. (From the Smithsonian Report for 1893.) Octavo pamphlet of 22 pages; illustrated with 2 maps.

No. 959. The Migrations of the Races of Men Considered Historically, by Prof. James Bryce. (From the Smithsonian Report for 1893.) Octavo pamphlet of 22 pages

No. 960. The "Nation" as an Element in Anthropology, by Daniel G. Brinton. (From the Smithsonian Report for 1893.) Octavo pamphlet of 12 pages.

No. 961. Summary of Progress in Anthropology, by Otis Tufton Mason. (From the Smithsonian Report for 1893.) Octavo pamphlet of 29 pages.

No. 962. North American Bows, Arrows, and Quivers, by Otis Tufton Mason. (From the Smithsonian Report for 1893.) Octavo pamphlet of 50 pages; illustrated with 57 plates.

No. 963. Oriental Scholarship during the Present Century, by Prof. Frederick Max Müller. (From the Smithsonian Report for 1893.) Octavo pamphlet of 20 pages.

No. 964. Stone Age Basis for Oriental Study, by Prof. E. B. Tylor, F. R. S. (From the Smithsonian Report for 1893.) Octavo pamphlet of 8 pages.

No. 965. Biographical Sketch of Henry Milne-Edwards, by M. Berthelot. (From the Smithsonian Report for 1893.) Octavo pamphlet of 19 pages.

No. 973. Report of S. P. Langley, Secretary of the Smithsonian Institution, for the year ending June 30, 1894. Octavo pamphlet of iii + 88 pages; illustrated with 1 text figure and 4 plates.

III. SMITHSONIAN ANNUAL REPORTS.[1]

No. 925. Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution to July, 1893. This volume contains the journal of proceedings of the Board of Regents at the annual meeting, held January 25, 1893; the report of the executive committee of the board for the year; acts and resolutions of Congress relative to the Institution, and the report of the secretary of the Institution; concluding with the general appendix, in which are given the following papers: "The wanderings of the North Pole," by Sir Robert Ball, F. R. S.; "The great lunar crater Tycho," by A. C. Ranyard; "The early temple and pyramid builders," by J. Norman Lockyer; "Variable stars," by Prof. C. A. Young; "The luminiferous æther," by Sir George G. Stokes; "Atoms and sunbeams," by Sir Robert Ball, F. R. S.; "Fundamental units of measure," by T. C. Mendenhall; "Photography in the colors of nature," by F. E. Ives; "Photographs in natural colors, by the process of L. Lumiere," by Leon Warnerke; "Electric-spark photographs of flying bullets," by C. V. Boys, F. R. S.; "Magnetic properties of liquid oxygen," by Prof. James Dewar, F. R. S.; "The prob-

[1] The papers in the general appendix of the annual reports are issued separately, as pamphlets, and are noted under Miscellaneous Collections.

lem of flying," by Otto Lilienthal; "Practical experiments in soaring," by Otto Lilienthal; "Phenomena connected with cloudy condensation," by John Aitken, F. R. S.; "On chemical energy," by Dr. W. Ostwald; "The American chemist," by Prof. G. C. Caldwell; "The highest meteorological station in the world," by A. Lawrence Rotch; "The Mont Blanc observatory;" "Relations of air and water to temperature and life," by Gardiner G. Hubbard; "The ice age and its work," by A. R. Wallace; "Geologic time, as indicated by the sedimentary rocks of North America," by Charles D. Walcott; "The age of the earth," by Clarence King; "The renewal of Antarctic exploration," by John Murray, LL. D.; "The North Polar Basin," by Henry Seebohm, F. L. S., F. Z. S.; "The present standpoint of geography," by Clements R. Markham; "How maps are made," by W. B. Blakie; "Biology in relation to other natural sciences," by J. S. Burdon-Sanderson; "Field study in ornithology," by H. B. Tristram, F. R. S.; "The so-called Bugonia of the ancients," by C. R. Osten-Sacken; "Comparative locomotion of different animals," by E. J. Marey; "The marine biological stations of Europe," by Bashford Dean; "The air and life," by Henry de Varigny; "Deep-sea deposits," by A. Daubrée; "The migrations of the races of men considered historically," by Prof. James Brice; "The Nation as an element in anthropology," by Daniel G. Brinton; "Summary of progress in anthropology," by Otis Tufton Mason; "North American bows, arrows, and quivers," by Otis Tufton Mason; "Oriental scholarship during the present century," by Prof. Frederick Max Müller; "Stone age basis for oriental studies," by Prof. E. B. Tylor, F. R. S.; "Biographical sketch of Henry Milne-Edwards," by M. Berthelot; the whole forming an octavo volume of xliv+763 pages; illustrated with 10 figures in the text and 94 plates.

No. 967. Report of the United States National Museum; Annual Report of the Board of Regents of the Smithsonian Institution, showing the operations, expenditures, and condition of the Institution for the year ending June 30, 1893. This volume comprises two parts: Part I. Report of the Assistant Secretary in charge of the National Museum, showing recent advances in museum methods, special topics of the year, work of the scientific departments, administration, etc. Part II. Papers describing and illustrating collections in the Museum, as follows: "The poisonous snakes of North America," by Leonhard Stejneger; "Chinese games with dice and dominoes," by Stewart Culin; "The onyx marbles, their origin, composition, and uses, both ancient and modern," by George P. Merrill; "The cowbirds," by Maj. Charles Bendire; "Primitive American armor," by Walter Hough; "The weapons and wings of birds," by Frederic A. Lucas; "Notes on the ethnology of Tibet, based on the collections in the United States National Museum," by William Woodville Rockhill; "Two Persepolitan casts in the United States National Museum," by Cyrus Adler; Museum collections to illustrate religious history and ceremonials," by Cyrus Adler; "If public libraries, why not public museums?" by Edward S. Morse. The whole forms an octavo volume of xxi + 794 pages, illustrated with 116 test figures and 187 plates. (This volume had been issued as a public document but the Smithsonian had not received its quota for distribution at the close of the year.)

IV. PUBLICATIONS OF THE BUREAU OF ETHNOLOGY.

The Bureau of Ethnology publications during the year included the eleventh and twelfth Annual Reports, Volume IX of Contribution to North American Ethnology, and five Bulletins as enumerated by the Director of the Bureau in his report.

V. PROCEEDINGS AND BULLETIN OF THE UNITED STATES NATIONAL MUSEUM.

The Museum publications are enumerated in detail in Appendix I and need not be repeated here.

Respectfully submitted.

A. HOWARD CLARK.

Mr. S. P. LANGLEY,
Secretary of the Smithsonian Institution.

GENERAL APPENDIX

TO THE

SMITHSONIAN REPORT FOR 1895.

ADVERTISEMENT.

The object of the GENERAL APPENDIX to the Annual Report of the Smithsonian Institution is to furnish brief accounts of scientific discovery in particular directions; reports of investigations made by collaborators of the Institution; and memoirs of a general character or on special topics that are of interest or value to the numerous correspondents of the Institution.

It has been a prominent object of the Board of Regents of the Smithsonian Institution, from a very early date, to enrich the annual report required of them by law with memoirs illustrating the more remarkable and important developments in physical and biological discovery, as well as showing the general character of the operations of the Institution; and this purpose has, during the greater part of its history, been carried out largely by the publication of such papers as would possess an interest to all attracted by scientific progress.

In 1880 the Secretary, induced in part by the discontinuance of an annual summary of progress which for thirty years previous had been issued by well-known private publishing firms, had prepared by competent collaborators a series of abstracts, showing concisely the prominent features of recent scientific progress in astronomy, geology, meteorology, physics, chemistry, mineralogy, botany, zoology, and anthropology. This latter plan was continued, though not altogether satisfactorily, down to and including the year 1888.

In the report for 1889 a return was made to the earlier method of presenting a miscellaneous selection of papers (some of them original) embracing a considerable range of scientific investigation and discussion. This method has been continued in the present report, for 1895.

ATMOSPHERIC ELECTRICITY.[1]

By Prof. Arthur Schuster, F. R. S.

It is hardly possible to imagine that the first experimenter who obtained an electric spark sufficiently strong to produce a sensible sound should not at once have been struck by the fact that he was in the presence of thunder and lightning on a small scale. We find, indeed, in various writings from the early days of electrical machines a number of suggestions that the thunderstorm is an electrical phenomenon; but to Benjamin Franklin belongs the merit of having perceived that a direct experiment was needed to prove what so far was only a guess. In an article entitled "Opinions and conjectures concerning the properties and effects of the electrical matter arising from experiments and observations made at Philadelphia, 1749," the following passage occurs:

"To determine the question whether the clouds that contain lightning are electrified or not, I would propose an experiment to be tried where it can be done conveniently. On the top of some high tower or steeple place a kind of sentry-box, big enough to contain a man and an electrical stand. From the middle of the stand let an iron rod rise and pass, bending out of the door, and then upright 20 feet or 30 feet, pointed very sharp at the end. If the electrical stand be kept clean and dry, a man standing on it, when such clouds are passing low, might be electrified and afford sparks, the rod drawing fire to him from a cloud.

"If any danger to the man should be apprehended (though I think there would be none), let him stand on the floor of his box, and now and then bring near to the rod the loop of a wire that has one end fastened to the leads, he holding it by a wax handle, so the sparks, if the rod is electrified, will strike from the rod to the wire and not affect him."[2]

The experiment suggested by Franklin was successfully performed in Marly (France), by D'Alibard, on May 10, 1752,[3] in London by Canton, in Spital square, on July 20, 1752, and by Wilson, in Chelmsford,

[1] Discourse delivered before the Royal Institution of Great Britain, by Prof. Arthur Schuster, F. R. S. Printed in Nature, No. 1366, Vol. LIII, January 2, 1896.

[2] "Experiments and observations on electricity made at Philadelphia, in America," by Benjamin Franklin, LL. D. and F. R. S. (London, printed for David and Henry, and sold by Francis Newbery, 1769, p. 66.)

[3] Ibid., p. 107.

Essex, on August 12 of the same year. Franklin himself describes having used a kite in Philadelphia in a letter dated October 19, without giving the date of his observations. But this must be supplied in some passage which I have not been able to find, for Rosenberger ("Geschichte der Physik," Vol. II, p. 316) mentions that it was done in June.

Franklin's disbelief in the dangerous character of the experiment must have received a severe shock when he heard of the death of G. W. Richmann, who, in the year 1753, was killed by an electric discharge drawn from the clouds by means of a kite.

The thunderstorm is the most impressive effect of atmospheric electricity, though it is rivaled in beauty by the aurora, and in interest by the many phenomena of daily occurrence which are only made perceptible to us by proper instruments. In a lecture delivered before this institution on May 18, 1860, Lord Kelvin described the delicate electrical appliances constructed by him for the more accurate observation of atmospheric electricity. The problems then for the first time clearly stated gave a powerful and still lasting impulse to the investigation of atmospheric electricity, and though no decisive answer can be given to all the questions raised in that lecture, recent researches have brought us somewhat nearer to their solution.

Observations which may be made every day and at every place have shown that the earth is electrified, whatever the weather may be. In the language of the older theories, which we can not as yet altogether abandon, we say that the earth is covered with negative electricity, or, in modern phraseology, we express the same idea by the statement that we move about in an electrified field, that electric lines of force stretch through the air from the ground, from our bodies, and from everything which is exposed to the sky overhead. The strength of this electric field is not at all insignificant. If we wish to produce it artificially between two parallel plates kept at a distance of 1 foot, we should have to apply an electromotive force sufficient—and sometimes more than sufficient—to light up the incandescent lamps which illuminate our dwellings. The electric force is comparatively weak in our country, but 50 volts per foot are constantly observed, and 100 volts are not uncommon; but in drier climates the amount of the force may be considerably in excess of these figures.

If we fix our minds on the lines of force starting from the surface of the earth, we are at once led to ask, Where is their other end? Do they curve round and back again to earth? Do they end in the dust which everywhere surrounds us, or do they reach up to the clouds? Do they pass through the clouds and end where invisible particles separate the sunset red from the midday blue? Or, finally, do they leave the earth altogether, and form intangible bonds between us and the sun, the stars, the infinity of space? These are not idle questions, and we can not be said to have solved our problem unless some definite

answer is given to them. The last mentioned view, propounded originally by Peltier, and latterly supported by Exner, is the simplest. If we could allow that the earth, once electrified negatively, could remain electrified forever, the corresponding positive electrification being outside our atmosphere altogether, the chief difficulty of atmospheric electricity would be removed, and the normal fall of potential at the surface would be explained by the permanent negative electrification of the surface.

Unfortunately this view, to be tenable, has to assume that the atmosphere is a complete nonconductor to the normal electric stress, and this is known not to be the case. We know of several causes which break down the insulating properties of air. If two pith balls are electrified and repel each other, and a match be lit in their neighborhood, the pith balls come together, showing that they have lost their charge, and consequently that the flame of the match has destroyed the insulating power of air. It is not only the flame itself which conducts, but also the gases rising from the flame.[1] The following experiment will prove this. In Fig. 1, Plate I, A represents a metallic tube bent round at the upper end, and containing at its lower end a Bunsen burner in metallic contact with the tube, which is also connected to an electroscope. The tripod T, which supports the tube, is insulated by blocks of paraffin. A Leyden jar L, on a separate support, is placed so that the knob stands at about the level of the upper part of the tube, which acts as chimney to the flame. The knob of the jar may be a few inches away from the opening of the chimney, and not necessarily in a line with it. The experiment succeeds, although the gases rising from the burner may not come into contact with any part of the jar. The jar is charged, and care must be taken that no fibers of dust attach themselves either to the jar or chimney. I have found it convenient to join a piece of amalgamated zinc to the end of the chimney. Under these circumstances the charge of the jar will be found to leak across to the tube, and the leaves of it will diverge. If, as in Exner's form of electroscope, the leaves, on reaching a certain divergence, discharge by forming a contact with earth-connected plates C C′, the charging and discharging can be watched for a long time. It will be noticed that the flame, being altogether surrounded by a tube of the same potential, cannot be active in this case, but the conductivity must be due to the gas as it escapes from the chimney.

It follows from these experiments that every fire burnt on the surface of the earth and every chimney through which products of combustion pass act like very effective lightning conductors, and would consequently discharge, slowly but surely, any electrification of the surface of the earth. The peculiar immunity of factory chimneys against damage by lightning appears from statistics collected by Hellmann in

[1] The most complete investigation of the conduction of gases rising from flames is contained in a series of papers by Giese (Wiedemann's Annalen, Vol. XVII).

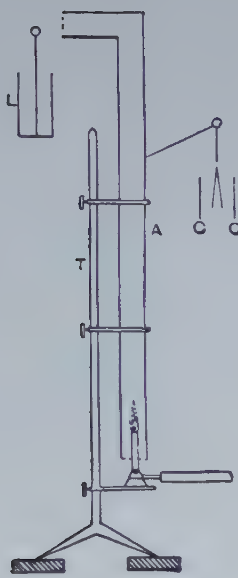
Schleswig-Holstein,[1] for while 6.3 churches per thousand were struck, and 8.5 windmills, the number per thousand of factory chimneys was only 0.3.

Franklin was acquainted with the action of flames. He also discovered that no charge can be given to a red-hot iron ball, a fact which seems to have been forgotten until rediscovered in our own times by Guthrie. Franklin also tried the action of sunlight, but obtained no result. Had he performed the experiment with carefully-cleaned zinc, he would have anticipated one of the most striking of Hertz's discoveries. We now know that a negatively-charged surface will discharge into air when illuminated by strong violet light, and sunlight will be sufficient with specially sensitive materials. This action has been investigated in detail by Elster and Geitel, who have not, however, succeeded in obtaining results with sunlight acting on such bodies as we know the earth's crust to be made of. So far, then, we have no experimental evidence to include light as an active agent in the phenomenon of atmospheric electricity.

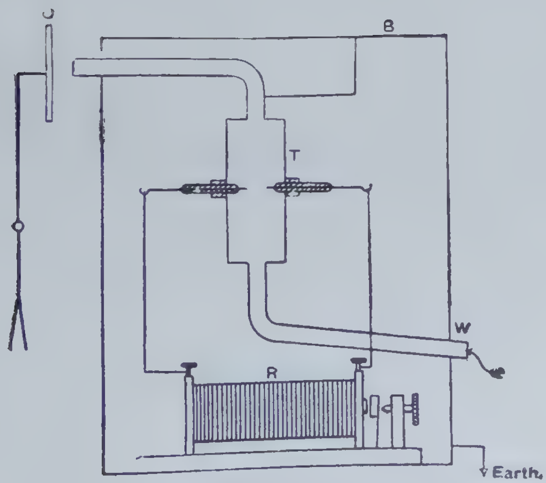
We possess in the electric discharge itself a very powerful and probably very generally active means of breaking down the insulating power of air. Some of the experiments (Proc. Roy. Soc., Vol. XLII) which I described some years ago to prove this were objected to on the ground that it might not be the discharge itself, but the ultra-violet light sent out by the luminosity of the discharge, which was active. The following form of the experiment conclusively shows that the discharge acts independently of light.

In Fig. 2, Plate I, R represents a Rhumkorff coil entirely surrounded by a metallic box B, which is connected to earth. The terminals of the coil lead to two electrodes inside a metallic tube T, which is also kept at zero potential. This tube is arranged so that a current of air can be blown through it. The air, on escaping through the tube, is made either to impinge on or to pass near a metallic plate connected to a charged electroscope. Under these circumstances the electroscope is not discharged either by a current of air alone or by the coil alone; but as soon as the air is blown through the apparatus while the sparks are passing and then made to impinge on the plate C, the electroscope is instantaneously discharged. The experiment succeeds when a plug of cotton-wool is inserted at W to stop the action of the dust; but a plug of cotton-wool at the other end diminishes the action so much that I am doubtful whether the effect then really exists there. I am, so far, not inclined to believe that the action is due to dust, but rather that the cotton-wool acts in increasing very considerably the interval which elapses between the time at which the spark acts and the time at which the sparked air passes out of the tube. The effect may be observed

[1] "Veröffentl. des kgl. preuss. stat. Bureaus," 1886, p. 177, quoted by Bebber, "Meteorologie," p. 245.



1



2

EXPERIMENTS WITH ATMOSPHERIC ELECTRICITY.

even though the tube L is lengthened by an addition of another piece 3 feet or 4 feet long.

Several phenomena, one of which had been known for a long time, can be explained by the fact that the electric discharge changes the condition of the gas into a state similar to that of gases rising from flames. It is mentioned, for instance, by Faraday that electric sparks are liable to succeed each other along the same path, and it is known that the same holds for lightning flashes, facts which themselves point to a higher conductivity of air along the path of the previous discharge. A curious instance of a similar effect is afforded by lightning conductors, which are sometimes put up to protect overhead leads used for conveying a high tension current. Owing to the obvious impossibility of connecting the leads directly to earth, a small air gap is interposed, the idea being that the air gap will act as an insulator for the current the leads are intended to carry, but that if during a thunderstorm the potential rises sufficiently high to be dangerous, equalization may take place through the air gap to earth by means of a small spark. So far the air gap answers its purpose, but as soon as a spark passes through the gap it destroys the insulating power of the air, and the main current consequently takes a short cut through the gap. At Pontresina, in the Engadine, lightning conductors put up in this way are so sensitive that a flash of lightning several miles away causes a small spark by induction, and instantaneously puts out every electric lamp in the town.

If we accept the view that an electric discharge destroys the insulating power of the gas, it follows that the outer regions of the atmosphere must conduct, for we have ample reason to suppose that electric currents are passing continuously through those regions. The aurora borealis in the arctic regions is, according to Nordenskiöld's observations, a permanent phenomenon, and the diurnal changes of terrestrial magnetism show that in our latitudes electric currents traverse the air above us. However small a conductivity we may assign to the atmosphere, the earth could not remain electrified inside such a shell of partially conducting gases. Lord Kelvin drew the same conclusion in the Royal Institution lecture, on the assumption that gases at much reduced pressures cease to insulate. We may leave it an open question whether the normal electric stress could in itself cause a discharge in the outer regions; but we can not deny that under existing conditions these regions do not insulate, and Lord Kelvin's argument still holds good.

But the question of the ending of the lines of force—in other words, the location of the positive charge corresponding to the negative electrification of the surface of the earth—can only be solved by balloon or kite experiment, and we may briefly mention the more important results which have so far been obtained.

Observations made up to heights of about 1,000 feet seem to indicate a strengthening of the electric field, i. e., the fall of potential per meter

is greater at a height of, say, 200 meters than on the surface of the earth. The observations of Dr. Leonhard Weber (Elektrotechnische Zeitschrift, April, 1888) bring out this point clearly. In one case the fall of potential at a height of 350 meters was found to be six times that at the earth's level. This increase is in itself not surprising, if we remember that every particle of dust raised from the ground must itself be negatively electrified, and probably the observed increase in the electric force is sufficiently accounted for by the presence of electrified dust.

Observations made at greater heights in balloons, on the other hand, seem clearly to indicate that this increase soon ceases, and that a diminution already takes place at moderate heights. Thus the observations of Dr. O. Baschin (Meteorologische Zeitschrift, September, 1894) gave for the fall of potential in volts per meter the numbers 49, 28, 13 at heights of 760, 2,400, 2,800 meters respectively, and at a height of 3,000 meters no measurable fall at all could be obtained. These observations were made in clear weather. The balloon afterwards passed over a layer of clouds, and strong electric effects were noticed. Similar observations had been previously made by others (Andrée, Le Cadet, and Bornstein), and though the subject is by no means exhausted, we may take it as provisionally established that the lines of force of the normal electric field of the earth end within the first 10,000 feet or 15,000 feet. This result is of great importance, for it shows that in fine weather there must be a layer of positively electrified air permanently above us. Currents of air in this layer must affect the field as we observe it, and possibly the daily period may be due to changes in the currents of air at a moderate height. A fact discovered by Exner is of importance in connection with this subject. Observing at three different places (in a field close to Vienna; in St. Gilgen, on the Wolfgangsee, and on the hills near Venice), he found that whenever there was a strong south wind, with a clear sky, the normal electric force was always increased, and sometimes considerably (Wiener Akad. Sitzungsberichte, Vol. XCVI, 1887).

The daily changes show, with few exceptions, a remarkable uniformity at different places. There are in general two maxima of potential—one at 8 or 9 o'clock in the morning, and one in the evening. The evening maximum is the most marked, while at some places, and especially near towns, the morning maximum disappears. The same general features of the daily variation have been found to hold at a number of European stations, at Cape Horn, Melbourne, and in the Northern Arctic regions. If the variation is separated into two—one having a period of twenty-four hours and the other of twelve hours—the latter is found to agree in phase at widely different places on the earth's surface, while the former is found to vary to a much greater extent, and hence to be probably more affected by local circumstances. The remarkable researches of Hann have given a similar result for the

diurnal variations of the barometer, and we may reasonably conclude that the semidiurnal variation of atmospheric electricity is connected with the same circulation in the upper regions of the atmosphere which shows itself in the corresponding changes of pressure.

In addition to the more regular periodic changes, the electric stress observed in fine weather shows marked differences on different days and at different seasons. With respect to these, the researches of Prof. Franz Exner (ibid.) have led to the important result that there is a close connection, direct or indirect, between the amount of aqueous vapor present in the atmosphere and the fall of potential observed at the surface of the earth. If p_0 be the pressure of aqueous vapor present in centimeters, Exner deduces the equation for electric force P

$$P = \frac{A}{1 + kp_0},$$

where $A = 1300$, $k = 13.1$.

The formula agrees very well with observations in which the vapor pressure varied between 0.23 and 0.95, and it is especially to be remarked that it is the amount of vapor and not the humidity which determines the electric force. Observations made by Mr. E. Drory during a journey round the world fit in very well with Exner's formula, and observations made at such widely different places as Suez, Albany, Sydney, Colombo, and Penang showed a fall of potential practically identical with that calculated from the above formula, though the same constants were taken and the vapor pressure varied between 0.8 cm. and 2.2 cm.

Messrs. Julius Elster and Hans Geitel (Wiener Akad. Sitzungsberichte, Vol. CI, 1892) have followed up this research. Their investigations have shown a satisfactory agreement with Exner's formula, if the mean values of a number of observations in which the vapor pressure is approximately the same are considered. But individual numbers differ very widely from the mean, so that the formula can not be used to predict the normal fall of potential on any particular day. There is, perhaps, nothing surprising in the great divergence of such individual results if it is considered that we only observe the moisture near the surface of the earth, but are ignorant of the total amount of water in the column of air over the district in which the observations are carried out. The same authors have shown that an equally good agreement can be obtained if, instead of the amount of aqueous vapor, we take the intensity of active radiation as the determining circumstance. The light might be supposed to act on the general surface of the earth, as it does according to Hallwachs' observations on a metallic body, dissipating a regular charge. There are some difficulties in the way of this explanation, the most serious being the absence of experimental evidence that sunlight actually does act in the manner indicated on any substance forming part of the earth's surface. It is impossible at the present time to enter more fully into this subject, but attention

must be drawn to the very important indirect result, that there seems to be a connection between ultra-violet radiations and the amount of aqueous vapor present in the air.

The phenomena of atmospheric electricity have been studied at the mountain observatory established on the "Sonnblick," in Salzburg, at a height of 3,100 meters.

The important result has been established that the electric force is singularly constant. The great differences observed at low level between the electric field in summer and winter, or on dry and wet days, seems to be completely absent, and these facts tend to support the conclusion derived from balloon observation, that the positive ends of the lines of force are situated at a height of something like 10,000 feet.

Brief allusion must be made to some of the causes which alter to a marked extent the normal fall of potential. As the surface of the earth is negatively electrified, it follows that dust carried up by the wind must be electrified, and it is found, indeed, that in violent dust storms the laws of force near the surfaces are altogether distorted and reversed in direction. Werner Siemens (Pogg. Ann., CIX, 1860; Meteorologische Zeitschrift, 1890, p. 252) could, while standing on the top of one of the pyramids during a strong wind, charge an improvised Leyden jar sufficiently to obtain strong sparks. A casual observation of Elster and Geitel (Ziele und Methoden, p. 11) may prove significant. On March 7, 1889, the temperature in Wolfenbüttel was rising from −10° C. to + 2° C., a cirrus layer covering the sky. The fall of potential changed in the course of four hours from 1,302 volts per meter to −1,200 volts—that is, from a very exceptionally high fall to an equally strong gradient in the other direction. Although the atmospheric circumstances were anomalous, they seem in themselves not sufficient to account for the anomalous electrical effects, and the authors suggest that a possible explanation may be found in a violent dust storm which on the previous day was observed in Alexandria.

Fogs are generally found to increase the normal fall considerably, so that the drops of water must be taken as positively electrified.

Waterfalls considerably disturb the electric condition of the air in their neighborhood, the air surrounding the fall being charged negatively, sometimes to considerable distances.

Whether clouds in themselves are always electrified is very doubtful; they no doubt disturb and generally weaken the fall of potential at the earth's surface, but this may only be due to a displacement of a positively-electrified layer which balloon observations have shown to exist at a height of from 10,000 feet to 20,000 feet. While a cloud discharges rain, the electrical effects in the neighborhood of the place are the same as that in the neighborhood of a waterfall. The explanation is probably the same in the two cases, and by means of experiments, alluded to farther on, we may reproduce the negative electrification of air under similar circumstances.

Measurements of the electrification of falling rain or snow, simple as they appear at first sight, are beset with very serious difficulty. We owe the most complete investigation on the point to Messrs. Elster and Geitel (Wiener Sitzungsberichte, Vol. XCIX, 1890). They find no regularity in the electrification, though positive signs slightly preponderate with snow and negative signs with rain.

The approach of a thunderstorm announces itself by characteristic cumuli clouds, and the general atmospheric condition favorable to their formation is felt by many persons of nervous temperament. Many of us are accustomed to hear that "there is thunder in the air." Whatever the special feeling of "thunder" may be due to, it can not be an electrical effect, for electrical instruments delicate enough to detect a small fraction of the normal force, give no indications of the approach of a thunderstorm, and it is only when the cloud has begun to discharge rain or hail that strong electrical effects are noticed. During the thunderstorm the electroscope is, of course, much disturbed, and there are frequent and violent reversals of its indications.[1] The fact that no effects are observed at the surface of the earth during the approach of a thundercloud does not prove that there is no electrical separation, for we may imagine two oppositely electric layers at different levels producing a strong electric field between them, but only weak effects outside. That some such things may possibly occur is indicated by observations made in mountain districts, where violent electrical disturbances are observed previous to the formation of clouds (Trabert, Meteorologische Zeitschrift, 1889, p. 342). The cumulus cloud, from which the lightning strikes out, is nearly always associated with a cirrus layer above it, and the flash occurs more frequently upward or sideward between the clouds than down to earth. Under such circumstances it is clear that instruments on the surface of the earth can only very partially indicate the nature and distribution of electrical stress in the neighborhood of the cloud.

Thunderstorms seem always to be connected with a vortex motion, and meteorologists distinguish two kinds of thunderstorms. The first kind forms in the outlying portions of a large cyclonic system. The storms which occur in winter are mostly of this nature, and the vortex necessary for its formation is of the nature of a secondary disturbance. The thunderstorm which forms in summer, on the other hand, makes its own vortex, and is of a much more local character than that which is produced round a previously established barometric depression. The summer storm is much influenced by the character of a district. There are certain configurations apparently favorable to its formation, as is clearly brought out by the charts which have been made representing their frequency.

The route traveled over by the storm is affected by mountain ridges, and rivers also seem to offer a peculiar impediment. Many of them

[1] Weber, Elektrotechnische Zeitschrift, Vol. X: Elster and Geitel, "Ueber einige Ziele und Methoden luftelektrischer Untersuchungen," Wolfenbüttel, 1891.

are brought to an end either along their whole front, or only part of it, when they reach the banks of a large river.[1]

Some curious problems are presented by the detailed structure of lightning flashes. Although these lie outside the range of the present lecture, reference must be made to the very beautiful photographs of lightning flashes taken both in this country and abroad. The ordinary forms which lightning takes are familiar to all, but a good deal of mystery still surrounds the so-called globular lightning. The manner in which this form appears is best described in the words of eye-witnesses.

Dr. A. Wartmann gives to the Physical Society of Geneva the following account of what he saw:[2]

"At half-past 6 o'clock in the evening I drove from Versoix to Genthoud. On the Malagny road I heard the coachman say he did not know where he was. His eyes were so much fatigued by the frequent and intense lightning discharges that he was blinded and could not, even in the intervals, see the road, in spite of the good lanterns alongside. I stepped on to the box and took the reins. We had barely passed the principal gate of the grounds of Dr. Marcet when I became conscious of a bright and lasting luminosity behind me. Thinking it was a fire, I turned round, and saw, at a distance of, roughly, 300 meters, a ball of fire of about 40cm. diameter. It traveled in our direction with a velocity about equal to that of a bird of prey, and left no luminous trail behind. Just as the ball had overtaken us, about 24 meters to our right, it burst with a terrific noise, and it seemed to me as if lines of fire started from it. We felt a violent shaking, and remained blinded a few seconds. As soon as I regained power of distinguishing objects I saw that the horses had turned at a right angle to the carriage, with their chests in the hedge, with drooping ears and all signs of great terror. I returned on the following day to the place where I had seen the ball explode, but could find no sign of any damage. At a distance of 100 meters I found that a group of three trees, bordering a wood, had their upper branches singed, but it is not possible to say whether this was due to the discharge which I had seen."

The following is a translation of an account given by Mr. H. W. Roth (Meteorologische Zeitschrift, 1889, p. 231):

"During the thunderstorm of May 19, 1888, at about 6 p. m., a flash of lightning took effect which seems to me remarkable from a physiological point of view. The dealer Werner, from Ellerbruch, and his son (16 years old), with a one-horse conveyance containing rags, were on the road which leads from here to the village of Ottensen, about 3 miles away in a southwesterly direction. The father had been left a little behind, and the son was occupied in giving bread to the horses, when he found himself suddenly surrounded by light, and noticed a fiery ball, about the size of his fist, moving toward him along the back of the horse. Then he lost consciousness. He felt no concussion. The father, on approaching, saw the horse's limbs still contracting, and at first he thought his son was dead, but succeeded, after considerable efforts, in bringing him back to life in about three-quarters of an hour. The horse was dead."

[1] Bebber, "Meteorologie," p. 255; Bornstein, Archiv der Seewarte, VIII, 1885.

[2] Arch. des Sci. Phys. et Nat. (3) Vol. XXI, 1889. The above account is translated from the Meteorologische Zeitschrift, 1889.

Some curious statistics have been collected, especially in Germany, as to the damage done by lightning flashes. That damage seems to have increased to an enormous extent within the last fifty years, and although in cases of this kind statistics may easily be at fault, there seems no doubt about the reality of the fact, which may find an explanation in the partial cutting down of forests in those parts where thunderstorms chiefly occur. When lightning strikes into forests, it selects certain trees by preference. Thus, in the principality of Lippe, taking the percentage of beeches struck by lightning as unity, that for other trees is as follows: Oak, 48; spruce fir, 5; Scotch fir, 33.

The St. Elmo's fire, a continuous discharge from points and sharp angles, is often observed on board ship and in mountain districts during a storm. Its appearance was considered a sign of the approaching end of the lightning, and was looked upon with favor by the ancient sailors in the Mediterranean Sea, who gave to it the name of Castor and Pollux. There was another appearance called Helena, a bad omen, which by many is believed to have been another form of the St. Elmo's fire, and the present name has been stated to be a corruption of the word Helena. Some support is given to this view by the fact that the Emperor Constantine built a castle in the Pyrenees, which he named after his mother, Helena, and this castle seems to be referred to occasionally as St. Elne or St. Elme. But it is much more probable, as argued by Dr. F. Piper (Pogg. Ann., Vol. LXXXII, p. 317), that the word is derived from St. Erasmo, a bishop who came from Antiochia, and suffered a martyr's death at the beginning of the fourth century. He seems to have been specially considered the patron of Italian sailors. Churches and castles in Naples and Malta were called St. Erasmo and St. Ermo, and Ariosto describes St. Elmo's fires as St. Ermo's fires. The electric discharge which goes under this name has a different appearance according as it is the positive or negative electricity which escapes, and both kinds occur with about equal frequency.

Although we have not yet arrived at any satisfactory theory of atmospheric electricity, some progress has been made, and this account would not be complete without a short account of the views taken by men of science on the subject. The number of theories proposed is very considerable. Dr. Suchsland,[1] in a pamphlet published in 1886, gives an account of twenty-four, to which he adds one—his own. The year 1884 alone has given birth to four theories.

We may group the theories according to the origin they assign to the source of energy which is involved in the formation of the electric field. All the work we can perform is either derived from the sun or from the earth's rotation. There is, as far as I know, only one theory—that of Edlund—which makes the earth's rotation in space responsible for the separation of electricities in the atmosphere. But Edlund's views are not tenable in theory, and, even granting his deductions, the

[1] "Die gemeinschaftliche Ursache der elektrischen Meteore und des Hagels," H. W. Schmidt, Halle-a.-S.

normal fall of potential should, according to the views of the author, have a different sign in the polar and equatorial regions, which is contrary to the observed fact. This theory does not, however, exhaust the possibility of explaining atmospheric electricity as a phenomenon of electromagnetic induction, and it is not disproved that in some form or other the rotation of the earth's magnetic field may play a part in the origin of the electric field. The theories which take solar radiation as the source of the energy divide themselves into several groups. We may think of a direct thermoelectric or actinic action, but there is, so far, no experimental support to such views. One of the earliest and most natural suppositions is the belief in evaporation as a source of electrification. This was Volta's theory, and experiments have at various times been produced in its support; but so far no one has been able to invalidate Faraday's conclusion that whenever electrification seemed to appear as a consequence of evaporation, it was really due to secondary causes, such as the friction of the liquid spray against the sides of the containing vessel. Rejecting Volta's theory, there is nothing left but the belief in some form of contact or frictional electricity either between drops of water and air or water and ice, or any two of the various bodies present in the atmosphere. The possibility of contact electricity between a solid or liquid and a gas is not quite easy to submit to the test of experiment. If we rub two solid bodies together, we may, by separating them, investigate the electric field produced; but, supposing we have a drop of water surrounded on all sides by air, the water may be covered with an electric layer of, say, positive electricity, the air in contact with the water with the opposite kind, and it is not at all clear how we could experimentally demonstrate the difference of potential between the air and the drop which is thus produced. A current of air flowing past the drop might carry away some of the negative layer, and in this way an electric field may be established while clouds are forming, but the conditions necessary for an experimental demonstration would be very difficult to realize. Two methods have been devised which practically demonstrate some form of contact electricity between gases and water.

Lenard, wishing to imitate the electric field observed in the neighborhood of waterfalls, has established by careful experiment a number of important facts, which are all consistent with the following explanation. If we imagine two oppositely electrified layers at the surface of a drop of water such as has been referred to, and if the drop falls on to a layer of the same liquid, or if similar drops impinge on each other, the difference of potential produced by the fusion of the surface layers becomes greater than is consistent with equilibrium. For, taking the case of drops falling into a mass of water contained in a cylindrical vessel, the extent of surface between air and water is not increased by the falling drops, and we must imagine that surface to be already covered with a sufficient electrical sheet to establish the required dif-

ference of potential. The electrification of the drops is, therefore, not wanted, and a change in the distribution takes place. The natural supposition would be that this equilibrium would be restored very quickly through the surface of the water, but a certain time seems to be required for this. Meanwhile, the strong current of air which in Lenard's experiments is brought down with the water drops carry some of the electricity away, the water remaining positive. More recent experiments of Lord Kelvin's, with air bubbling through water, point similarly to contact forces between gases and liquids, and in these experiments also it appears that a considerable time is required to establish electric equilibrium between a gas and a solid. Lenard finds very important differences caused by small impurities in the water, the water acting much more strongly when it is pure. If it contains as much salt as is contained in the sea, the effect is reversed, and the air becomes positively electrified. The explanation which is given above is practically that of Lenard, whose observations have been confirmed and further extended by Prof. J. J. Thomson. These experiments, no doubt, account for the behavior of air in the neighborhood of waterfalls, and they probably also explain the negative electrification of air in the neighborhood of districts in which rain is falling. The strong positive electrification of mist may also be due to the same cause.

There seems to be no doubt that the formation of a cloud is often accompanied by electrical effects. A few years ago, descending from the Dent Blanche, I found myself, after sunset, at a height of about 12,000 feet. A current of air was apparently blowing up the valley which stretches from Evolena toward Ferpecle, and I could observe a cloud condensing below me at a height a little below the snow line. As night came on and we continued our descent over the glacier and down the valley, a series of electric discharges were noticed between the cloud, which was lying in a deep-cut valley, the sides of the mountain, and the blue sky overhead. Here the moist air was evidently streaming through the cloud, depositing its moisture in the form of drops, and it seemed the most natural explanation at the time that the air left the cloud in an electrified state.

But while by means of experiments we have been able to produce some of the phenomena of atmospheric electricity, we have other important effects which can not be accounted for in so simple a way. The electric discharges during a thunderstorm give evidence of electric fields which could hardly be explained by contact electricity between drops of water and air alone. The fact that thunderstorms are nearly always connected with the formation of hail, and Faraday's experiments showing that water rubbing against ice becomes negatively electrified, is made use of in the theories of Sohnke and Luvini. It is quite likely that there is some truth in these theories. Their weak point lies in the difficulty of seeing how particles of ice and water can be first sufficiently mixed to allow of friction, and then become sufficiently

separated to produce an electric field of such magnitude as we know must exist in a thundercloud.

It is to be remarked, however, that the laws of contact electricity must be applicable to gases as well as to solids, and that if water becomes positive when rubbing against air, and negative when rubbing against ice, there must be a strong contact difference between ice and air. In other words, it does not matter whether there is direct friction between ice and water, or whether the air forms an intermediate body. We may imagine air rising through a cloud containing drops of water negatively electrified, and then passing through an ice cloud having its negative electricity increased, thus leaving the ice and water particles at a difference of potential which may, by a fusion of the drops, increase sufficiently to produce a lightning discharge. This seems to me the most plausible theory which, in the present state of our knowledge, can be formed. As regards the permanent negative charge of the earth's surface, the time has not yet arrived for forming a definite opinion. Although we know that the earth, once electrified, would gradually lose its charge into the atmosphere, yet we can express no opinion as to the rate at which the loss is going on. That loss may be exceedingly slow, and consequently equilibrium might be attained by a very small preponderance of negative electricity brought back to its surface through some cause or other. Rain, as has already been mentioned, is more frequently electrified negatively than positively in our own climate, and though we do not know how far this holds in the tropical belt, it is at any rate possible that the surface of the earth may in this way alone make up for the loss. We may also reasonably think that Lenard's observation on salt water may account for the permanent charge. Every wave that breaks into spray under the action of a strong wind would leave the water negatively electrified, the air carrying away the positive charge. It would be of great interest to possess observations on atmospheric electricity on board ship while waves are breaking in the neighborhood. So far we have only Exner's observations to guide us, who found, while observing at Lavinia, in Ceylon, that the spray from breaking waves affected the indications of the electrometer, proving its positive electrification (Wiener Akad. Sitzungsberichte, Vol. XCVIII).

But although the loss of electricity from the earth's surface may be very slow, it is equally possible that it is considerable. We shall not be able to treat this question satisfactorily until we have some clearer notion of the causes of the aurora. We know that the aurora implies electric currents, and the circuit of these currents may lie completely within the earth's atmosphere, and have nothing to do with the observed fall of potential near the ground. It is also possible that the body of the earth forms part of the electric circuit, and if that is the case, there must be across different parts of the surface an outward and inward flow of positive electricity. Such a discharge could not fail to

influence the phenomena we have discussed, and it seems probable that we should have some evidence derived from observation if the aurora was always accompanied by discharges through the earth's surface. Except in the polar regions, these auroræ do not seem to affect the normal fall of potential. There is a third view we may take as to the circulation of electric currents indicated by the aurora—the return current may take place in space outside the earth's atmosphere. A good deal might be said in favor of this view, and the rotation of the earth's magnetic field in space might be a sufficient cause for the production of these currents; but this is not the place to enter further into this question.

Calculations made from observation on the height of the aurora have generally resulted in an altitude of from 100 to 200 miles, except in the polar regions, where the aurora seems occasionally to descend to a much lower level. It has also been noticed that auroræ are associated with certain bands of cirrus clouds, and this seems to indicate that although the luminous phenomena is sufficiently intense to be observed at only great heights, yet the electric phenomena may descend to the level of the cirrus.

As regards the connection between the aurora and the sun-spot period, further observations in the polar regions are needed. On the one hand, we have Paulsen's[1] statement, derived from observations in Greenland, to the effect that the greatest number of auroræ are seen when sun spots are at their minimum—that is, at a time when in our own latitudes the number is smallest; and, on the other hand, we have Nordenskiöld's observations, which seem to point in the opposite direction. In a publication which contains much important matter on the geographical distribution and form of the aurora borealis, Nordenskiöld contrasts the appearances he has observed in the *Vega* during the winter of 1878–79, passed in the Bering Straits, with that previously observed in 1872–73 to the north of Spitzbergen. According to this author, the auroræ, during the minimum sun-spot period in 1878–79, were "hardly worthy of his notice by the side of those observed in 1872–73." But although only faintly luminous, the auroræ of 1879 were persistent and regular in shape. They did not affect the magnetic field, and seemed to show a regular and continuous, though weak, electric discharge. The arc and streamers in 1872 were much more brilliant and much more irregular. Some objection may be raised against these observations, in so far as they refer to different places, and local circumstances may have affected the phenomenon; but, in the face of the very careful description he gives us, we can not as yet accept Paulsen's results without further confirmation.

The problem of atmospheric electricity, like that of terrestrial magnetism, presents special features in the arctic regions, and until we

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[1] Paulsen, "Danske Videnskab. Selskabs Forhand.," 1889. (I have not seen the original memoir, but only an abstract in the Jahrbuch der Astronomie und Geophysik, 1890.)

possess a greater number of observations in those little accessible parts of the earth's surface, many important problems can not be satisfactorily solved. Arctic and antarctic expeditions are of interest to scientific men, not because they care much whether we get a few miles nearer the pole, but because a well-conducted party collects invaluable information on its journey. Although much remains to be done in the regions surrounding the north magnetic pole, our knowledge in the southern hemisphere is almost disgracefully inadequate, and it is to be hoped that before long a well-equipped expedition may fill up to a certain extent the large gaps in our electrical and magnetical knowledge which at present stop so many of our researches.

But although investigations to be conducted in the arctic regions are of primary importance, we may do much nearer home in extending and completing existing information. Instrumental appliances and methods of observation, originally put into a satisfactory state by Lord Kelvin, have been improved, especially by Mascart, Exner, Elster, and Geitel. One of our most crying wants at present is a series of continuous observations by means of self-registering instruments in places where the neighborhood of a town or other local circumstances do not interfere with the normal changes. The Greenwich Observatory, to which we look for help in such matters, is placed in the difficulty that the daily variations there observed are markedly different from those in the majority of places, and it is probable that the nearness of London is fatal to any generally useful series of observations of atmospheric electricity being conducted in our national observatory.

THE GENERAL BEARINGS OF MAGNETIC OBSERVATIONS.[1]

By Ettrick W. Creak.

If necessity be the surest prompter of invention, it is not too much to say that the necessity of the navigator has been a most potent factor in producing the observer of the elements of terrestrial magnetism. The traveler on land might rest during darkness until daylight enabled him to resume his journey; but the seaman on the trackless ocean was dependent upon the indications of his compass by day and night; and after the discovery of Columbus that the magnetic declination or variation of the needle from the direction of the geographical north varied in amount with the latitude and longitude, a new impetus was given to observation.

The publication of Gilbert's grand discovery that the earth is a magnet and the director of the freely suspended needle, followed by the discovery of the secular change in the value of the declination, naturally added to the desire of both landsmen and seamen to know as much as possible concerning that great magnet, both from purely scientific reasons and to meet the practical ends of the navigator. Thus the seventeenth and eighteenth centuries were remarkable for the number of observers both of the magnetic dip and declination.

So important had a correct knowledge of the declination become to the requirements of navigation, as early as the close of the seventeenth century, that Halley, under the immediate auspices of the Government, made his celebrated voyage over the Atlantic Ocean in a man-of-war, in order that intelligent observation should set at rest much that was doubtful. The results of this voyage, combined with the observations of previous navigators, were embodied in his celebrated chart of lines of equal value of magnetic variation or declination, the first of its kind and of so convenient a form that charts of equal values of the three magnetic elements are to this day the most acceptable form for representing the combined results of magnetic observations made over large areas of sea and land, as well as of the special magnetic surveys which in recent years have been made in various countries.

[1] From Science Progress, Vol. V, No. 26, April, 1896.

Here we may pause to consider the word declination as applied to the angle which the direction of the horizontal magnetic needle makes with the true meridian. Many magneticians object to the word, but no better has yet been proposed, or at any rate accepted; the result being that while observers on land use the term, seamen adhere firmly to the expression "variation of the compass." This is as might be expected, when it is remembered that navigators look upon the word declination as connected with the position of the sun and other heavenly bodies, and would find it most inconvenient to have the same word in daily use, meaning two totally different things.

During the eighteenth century charts of the magnetic declination were published by Mountaine and Dodson, Bellin, and Churchman, and for their time may be considered as fair approximations to the truth. Churchman's design was not only to give values of the declination but to furnish the seaman with a means of ascertaining the longitude—an ambitious project, especially as we now know there were probably considerable elements of error in these charts, caused by local magnetic disturbance of the observing compass on land, and from the iron used in construction disturbing the compass on board the ships.

This latter source of error was only beginning to be viewed in its true light at the close of the eighteenth century.

In the years 1801–1802 Commander Flinders of H. M. S. *Investigator*, then surveying the southern coasts of Australia, found that when his vessel's head was north or south by compass the observed declination agreed very nearly, but when she lay with her head east or west, it differed largely. Moreover these errors on the east and west points of the compass had the opposite sign to those observed in England.

Flinders, however, had supplemented the existing scanty knowledge of the distribution of the dip over navigable waters by several observations of his own in northern and southern latitudes, and from these he drew the conclusion that the errors in the declination observed on board ship were caused by magnetism induced by the earth in the vertical iron of the ship, and changed in value proportionally to change of dip. Here Flinders was wrong, as the errors were really proportional to the tangent of the dip.

In spite of this mistake he was enabled, from his knowledge of the dip, to conceive the idea of so placing vertical bars of iron that they produced an equal and opposite effect on the compass to that of the ship in all latitudes, and thus invented what is now called the Flinders bar, one of the most important correctors of compass disturbance in the iron and steel ships of the present day.

In 1814 Flinders induced the Admiralty to have experiments made on board men-of-war at Portsmouth, Sheerness, and Devonport, to ascertain the amount of the magnetic disturbance of the compass caused by the iron in each ship. The chief reason for making these experiments was to show the necessity for ascertaining and applying

these errors to insure the safe navigation of the ships, but it had also a direct bearing in enabling observers to eliminate the hitherto inexplicable divergencies in the values of the declination observed in different ships in the same geographical position. The results of these experiments bore no immediate fruit, for with the death of Flinders the subject was temporarily neglected.

In 1819, Hansteen published his Magnetismus der Erde with an atlas containing charts of the elements declination and dip for different epochs between the years 1600 and 1787. These charts were in a large measure compiled from observations made with imperfect instruments and subject to the causes of error already mentioned attending both land and sea results. Hansteen, however, considered them of sufficient value to enable him to draw certain important conclusions with regard to the cause of the secular change of the magnetic elements. Thus, he not only concurred with Halley that the earth, considered as a magnet, had four poles or points of attraction, but computed their geographical positions. Further than this, he computed that to account for the secular change these four supposed poles revolved round the terrestrial poles, each pole occupying a widely different number of years to complete the revolution.

If these theoretical results had been true, a great advance would have been made not only in the science of terrestrial magnetism but in its practical bearing on the requirements of the present day.

Although Humboldt had about the year 1800 shown that the intensity of the earth's magnetism varied with the latitude, the general distribution of that magnetic element was so little known that we may with our present extended knowledge consider that Hansteen's conclusions were based on insufficient data. In fact the idea of the earth being a magnet with four poles has long since been abandoned in favor of there being one pole with two foci of intensity in each hemisphere, and reasons will be given further on which tend to throw doubt on there being any revolution of these two magnetic poles round their adjacent terrestrial poles.

Subsequently to Hansteen's charts there appeared those of the declination by Yeates, Duperrey, and by Barlow in 1836. These were useful to navigation, but helped very little toward the solution of the problem of the ever variable distribution of the earth's magnetism.

Besides this, by the year 1835 the iron-built ship had appeared on the ocean, and a correct knowledge of the three magnetic elements became a necessity in solving the problems which the magnetism of different iron ships presented.

With Gauss's invention of the absolute horizontal force magnetometer in 1833, many hitherto unknown movements of the magnetic needle of the highest interest were discovered, which with the coarser instruments previously in use lay concealed. This discovery gave the desired impetus to the scientific men of that epoch, and the period

included in the years 1835–1845 was "a time of unparalleled activity in the extension of systematic and accurate magnetical observations over the earth's surface."

Whilst most of the continental nations joined in this movement, the principal share in the work was divided between Germany, Russia, and England in Europe, and the United States in America. But before the splendid series of simultaneous observations made on the continent, and four British colonial observatories were organized, Gauss in 1839 published his general theory of terrestrial magnetism coupled with a series of charts of the three magnetic elements for the whole world, based upon observations made at ninety-two selected stations distributed over the earth's surface; and it may be remarked that Gauss's charts not only gave results in fair accordance with observation in explored regions, but also as afterwards proved in Antarctic latitudes hitherto unvisited by man.

The proof came in the years 1839–1843, when Ross's Antarctic voyage of exploration was carried out in the interests of terrestrial magnetism. Besides the importance of a knowledge of the general distribution of the magnetic elements in those regions, one great aim of this expedition was to reach the south magnetic pole. This was found to be impossible, but sufficient data were collected to give its approximate position. Whilst this Antarctic magnetic survey was being completed, that of British North America was also undertaken, with the result of the determination of the locality of one of the foci of greatest intensity in the northern hemisphere.

The results of these surveys formed, as will be well remembered, a valuable series of "contributions" to terrestrial magnetism by Sabine, and, coupled with every available observation between the years 1818 to 1876, formed the materials for the series of charts entitled "The Magnetic Survey of the Globe" for the epoch 1842–1845. Each map gave normal lines of equal values of the declination, inclination, and intensity. Although it may be said that from the Arctic circle to the Antarctic the direction of the lines was efficiently given by observation, the lines within those circles were largely taken from Gauss's computed lines modified to agree with observation.

Another difficulty in compiling these charts of Sabine's with accuracy lay in the uncertain knowledge of the secular change then available, and which had to be applied to observations made so far apart in time.

Sabine's charts are doubtless the best we have for the epoch 1842–1845, but in the light of the requirements of modern science they leave much to be desired as regards the Antarctic regions. The observations south of 60° south were made entirely on board ships, where the errors of the compass sometimes exceeded 50°, due to the horizontal forces in the ship, thus rendering accurate observations of the declination very uncertain and correction of the observed inclination very difficult; besides which there are no records of the ship's disturbing force in the vertical direction.

Naval requirements, however, did not permit of any delay in publishing magnetic charts affecting navigation, for in 1846 the hydrographer of the Admiralty requested Sabine to provide charts of the declination for the Atlantic Ocean from 60° north to 60° south. These were largely used until Evans's chart of the declination for the whole navigable world was issued in 1858.

The excellent work of Flinders already referred to, of ascertaining from his knowledge of terrestrial magnetism the chief cause of the deviation of the compass in wood-built ships, and providing a corrector for those deviations, had to be followed up on a much larger scale and with more exact methods in the iron-built ship, which, in that period of activity in terrestrial magnetic science—1835–1845—was rapidly increasing in numbers on the ocean.

Thus in 1835 observations were made on board iron ships showing that they acted as a magnet on their compasses, but there was nothing to show in the results what the causes of this condition of the iron ship were, until Poisson in 1838 published his celebrated "Memoir on the deviations of the compass produced by the iron in a ship." This was a rigorous mathematical investigation of the subject, showing that the deviations of the compass were due to induction in the ship by the magnetic force of the earth.

If the iron ship had simply been built for service in one locality, a limited knowledge of terrestrial magnetism would have sufficed to elucidate the causes of her magnetic condition; but she was destined to traverse every navigable sea over large changes of magnetic latitude, hence the necessity for an accurate knowledge of the distribution of magnetism over the great parent magnet, in order to determine the magnetic condition of her comparatively minute offspring the magnetized iron ship: and this at all times and in all places in the interests of navigation. Observations of the terrestrial magnetic elements were therefore an absolute necessity if iron-built ships were to be substituted for those of wood.

The ability to predict the deviation of the compass on change of latitude did not, however, satisfy Airy, for after a remarkable mathematical investigation of iron ship's magnetism of a less rigorous character than Poisson's, but sufficiently accurate for his purpose, he in 1839 proposed his methods of annulling the deviation of a ship's compass by means of magnets and soft iron, so arranged as to produce equal and opposite magnetic effects to that of the ship. Provided with Airy's admirable and simple directions this method of correction was comparatively easy in one latitude, but experience at sea, especially in voyages to the Cape of Good Hope, showed that every iron ship required a different application of Airy's correctors.

To discriminate between the amount that was to be corrected by permanent magnets, by horizontal soft iron, and by vertical soft iron, an accurate knowledge of the magnetic elements dip and intensity obtained from observations on land and at sea was essential.

Before dismissing the subject of the above application of magnetic observations, it may be remarked that we have now heavily armed protected steel cruisers steaming over all parts of the world with less change of deviation of the compass than the wood-built *Erebus* and *Terror* of Ross's Antarctic expedition, and this remarkable result could not have been achieved if the terrestrial magnetic observer had not done his work.

Moreover, if magnetic observations are not continued, the secular change of the magnetic elements will soon commence to mar the precision with which our rapidly-moving ships traverse the globe.

The voyage of the *Challenger* in 1872–1876 contributed the most valuable series of observations of the magnetic elements in modern times, when the large areas of the principal oceans traversed by that vessel during three and a half years are taken into consideration. These observations, combined with those taken from every available source, both British and foreign, between the years 1865–1887, formed the materials from which the magnetic charts of 1880 were compiled (see Vol. II, Physics and Chemistry, part 6, voyage of H. M. S. *Challenger*).

The *Challenger* only crossed the Antarctic circle at one point in longitude 78° east, and, therefore, although we know large secular changes to be going on south of 40° south, we have no measure of the amount, nor anything like an accurate knowledge of distribution of the earth's magnetism in those regions. This points to the necessity for a new Antarctic expedition.

In the year 1888 the late Prof. J. C. Adams was provided with a complete set of magnetic charts for the two epochs 1842–1845 and 1880 previously mentioned, and as it was known he had directed his profound mathematical ability to the analysis of the results contained in them, it was hoped that some new and important light might be thrown upon the bare facts presented. His lamented death occurred without his publishing any results.

If, however, reference be made to the report on the magnetical results of the *Challenger*, a discussion of the secular change is contributed, founded in a great measure on a comparison of those charts. The outcome of this discussion is to throw considerable doubt upon the theory that the motion of the magnetic poles round the terrestrial is the cause of secular change; in fact, that the magnetic poles remain fast, and we must look elsewhere for the cause, whatever it may be.

Magnetic observations have so far been considered in their all-important bearing as necessary to safe navigation in wood-built ships, and in a far higher sense as indispensable to that of the iron or steel-built ships which now cover the ocean, the magnetic charts hitherto generally required for these purposes being those on which normal lines of equal values have been given; but something more is now needed.

Observation in comparatively recent years has shown that not only

are there large "regional" magnetic disturbances extending over large areas of land, but that in moderate depths of water where the largest ship can navigate freely, the land below is also found to have considerable areas of local magnetic disturbance which, if not allowed for, may in thick or foggy weather lead ships into danger by seriously disturbing their compasses.

The United States has done excellent work in producing charts of isomagnetic lines, or charts in which the chief local magnetic disturbances are recognized, and the full results of observation recorded. The magnetic surveys of Rücker and Thorpe in the British Isles, of Moureau in France, of Rijckevorsel in Holland and elsewhere, have thrown considerable light on the magnetic conditions of those countries, but there remain whole continents to be covered by the observer.

The direction of the isómagnetics, too, from the deep sea to the dry land of the coasts is an extension of the subject which the observer has hardly touched as yet, but one affecting the safety of navigation, as well as the question that has been raised, whether the water areas of the globe are, as a whole, more or less magnetized than the land areas.

To possess charts of isomagnetic lines for even a few countries is an evidence of considerable advance in the knowledge of terrestrial magnetism, for if reference be made to Sabine's lines of intensity in his contribution on the magnetic survey of Northwest America it will be found that he rejected certain observations he considered abnormal and defective, which Lefroy, the observer, considered to be his best and naturally retained in his map; the result being a considerable difference in the form of the curves adopted by the two magneticians, Sabine giving normal curves, Lefroy isomagnetics.

Respecting the local disturbances of the needle which have been so clearly proved, the question naturally arises, Whence the cause of these disturbances? It is now believed by many, if not finally accepted, that Rücker and Thorpe have answered the question by the results of their laborious survey of the British Isles, coupled with Rücker's elegant investigations as to the permeability of specimens of the rocks taken from the localities in which magnetic disturbances were found. Their answer is to the effect that these disturbances, which have been found to extend over a region 230 miles long by about 110 miles broad, are due to induction by the earth's magnetism in rocks of different permeability, either present as in the basalts on the surface or concealed by superficial deposits.

These results are distinct from the extraordinary disturbances of the needle when in the immediate vicinity of permanently magnetized rocks, and when the radius of disturbance may be only as many feet as the extent of the regional disturbance is in miles.

The points of interest in the question of regional magnetic disturbance are not confined to the magnetician, for the geologist can not

afford to neglect the valuable information the magnetic needle affords. Thus although Rücker and Thorpe have since made a second and more elaborate survey of the British Isles, their remark of 1890 that "the kingdom can be divided into magnetic districts in which the relations between the direction of the disturbing forces and the main geological characteristics are so suggestive as to be worthy of careful statement and further investigation," not only holds good, but has received confirmation.

The mining engineer is deeply interested in a knowledge of the declination. Charts of normal lines are of great use to him whether above or below the earth's surface, but especially below when he has no other guide. To such an one a knowledge of regional magnetic disturbance as deduced from surface observations is most important, as it tells him that he is in the neighborhood of magnetic rocks, the disturbing effect of which on his compass needle may be far greater in the depths of his mine and turning it into a treacherous guide.

We have now considered magnetic observations in a measure from the point of view of the immediate practical results which their scientific treatment produces, but who will say in this great maritime nation that the work of magnetic observers, even if solely to make navigation possible, is not worthy of the fullest consideration?

There is besides a vast field of inquiry for the observer of terrestrial magnetism in unraveling the secrets of the earth considered as a magnet, and the ceaseless change of its magnetic condition which the needle tells us of, for which no immediate practical result can be foreseen, yet is worthy of the attention of the ablest physicists and most advanced mathematicians.

Inquiry into the causes of the secular change is one requiring the fullest attention, but observation has not yet done sufficient work. It certainly has done much in certain countries, and for a large portion of the world as regards secular change in the past, and data obtained for predicting future changes for a few years, but only one expedition has examined the Antarctic regions magnetically, and it is doubtful if any substantial progress will be made until a second expedition is made thither, one profiting by the experience of its precursor, and equipped with possibilities for work hardly hoped for by Ross.

It may be remarked in passing that a remarkable alteration in the amount of the secular change has been noticed in the declination and inclination at the following observatories: Bombay, Batavia, and Hong Kong about the period of the eruption of Krakatoa in 1883. This may be only a coincidence, but may it not also point to the possibility that the changes below the surface of the earth which culminated in that mighty explosion, and may still be at work, have had, and continue to have, magnetic effects which are recorded by the needles at those observatories?

Critical investigations have for many years been directed to the elucidation of the causes of the observed diurnal variations of terrestrial

magnetism. This work was long seriously retarded by the various methods adopted at different observatories for recording their results, obliging those who entered upon a comparison of such results to go through a tedious conversion of them into a common method. It may be said that the first large departure from this objectionable practice occurred when the international polar inquiry of 1882–1883 was undertaken by the various expeditions.

This was an important step in the right direction, but there remains much to be done, as shown by the ten reports of the British Association Committee on "the best means of comparing and reducing magnetic observations." Their last report consists of an able and suggestive paper by Dr. Chree, being the analysis of the results of five years' observations on "quiet days" at Kew, and is well worthy of attention as indicative of the present state of our knowledge as regards the diurnal variation of the three magnetic elements.

Such investigations only encourage one in the hope that the much required observations in southern latitudes may be undertaken. The observatories at the Cape and Melbourne could do invaluable work if it were carried out on the lines of Kew, for example.

Lastly, what more is there to be said about magnetic observations and their bearings? We do not know why the earth is a magnet, the cause of the secular change of its magnetism, why it is subject to solar diurnal, lunar diurnal, sidereal diurnal, and the other variations and disturbances, nor the cause of magnetic storms, although we can observe connections between them, earth currents, and aurorae. Whether the causes of all these exist below the surface of, or are external to, the earth, or are a combination of the two, has still to be learnt, and it seems hardly too much to hope that the restless needle will sooner or later be the means of opening up sources of knowledge invaluable to cosmical science, as well as to those only concerned with the planet upon which they dwell.

When the causes of the secular change are understood, there will be no difficulty in providing the navigator with magnetic charts for years in advance, much as the tides can now be tabulated for his use. In the latter case observation has done its work for several frequented ports, in the former case a vast amount remains to be done, and the word that goes forth is still, as Lord Kelvin thrice said on a kindred subject connected with ships' magnetism, "Observe."

RECENT PROGRESS IN OPTICS.[1]

By Prof. W. LeConte Stevens.

The reviewer who aspires to give an account of recent progress in any department of science is met at the outset by two causes for embarrassment. What beginning shall be selected for developments called recent? What developments shall be selected for discussion from the mass of investigations to which his attention has been called? So rapidly is the army of workers increasing, and so numerous are the journals in which their work is recorded, that the effort to keep up with even half of them is hopeless; or, to borrow a simile employed by the late Professor Huxley, "We are in the case of Tarpeia, who opened the gates of the Roman citadel to the Sabines, and was crushed under the weight of the reward bestowed upon her."

I have selected a single branch of physics, but one which can scarcely be treated rigorously as single. From the physical standpoint optics includes those phenomena which are presented by ether vibrations within such narrow limits of wave length as can affect the sense of sight. But these waves can scarcely be studied except in connection with those of shorter and of longer period. Whatever may be the instruments employed, the last one of the series through which information is carried to the brain is the eye. The physicist may fall into error by faulty use of his mathematics, but faulty use of the senses is a danger at least equally frequent. Physiological optics has of late become transferred in large measure to the domain of the psychologist, but he in turn has adopted many of the instruments as well as the methods of the physicist. The two can not afford to part company. If I feel particularly friendly to the psychologist, more so than can be accounted for by devotion to pure physics, it may be fair to plead the influence of old association. If I am known at all in the scientific world, the introduction was accomplished through the medium of physiological optics. But, with the limitations imposed, it is not possible even to do justice to all who have done good work in optics. If prominence is assigned to the work of Americans, it is not necessary to

[1] Address delivered by Prof. W. LeConte Stevens before the Section of Physics of the American Association for the Advancement of Science, at the Springfield meeting, August, 1895. Printed in Nature, No. 1367, Vol. LIII, January 9, 1896.

emphasize that this association is made up of Americans; but, with full recognition of the greater spread of devotion to pure science in Europe, of the extreme utilitarian spirit that causes the value of nearly every piece of work in America to be measured in dollars, we are still able to present work that has challenged the admiration of Europe, that has brought European medals to American hands, that has been done with absolute disregard of monetary standards; work has been recognized, even more in Europe than in America, as producing definite and important additions to the sum of human knowledge.

In drawing attention to some of this work it will be a pleasant duty to recognize also some that has been done beyond the Atlantic—to remember that science is cosmopolitan. The starting point is necessarily arbitrary, for an investigation may last many years and yet be incomplete. To note recent progress, it may be important to recall what is no longer recent.

LIGHT WAVES AS STANDARDS OF LENGTH.

You are therefore invited to recall the subject of an address to which we listened in this section at the Cleveland meeting in 1888, when Michelson presented his "Plea for light waves." In this he described the interferential comparer, an instrument developed from the refractometer of Jamin and Mascart, and discussed various problems which seemed capable of solution by its use. In conjunction with Morley he had already used it in an inquiry as to the relative motion of the earth and the luminiferous ether (American Journal of Science, May, 1886, p. 377), and these two physicists together worked out an elaborate series of preliminary experiments (ibid., December, 1877, p. 427) with a view to the standardizing of a metric unit of length in terms of the wave length of sodium light. By use of a Roland diffraction grating, Bell had determined the sodium wave length with an error estimated to be not in excess of one part in two hundred thousand (American Journal of Science, March, 1887, p. 167). Could this degree of accuracy be surpassed? If so, it must be not so much by increased care in measurement as by increase of delicacy in the means employed. The principle applied in the use of the interferential comparer is simple enough; the mode of application can not be cleary indicated without a diagram, but probably all physicists have seen this diagram, for it was first brought out eight years ago (ibid., December, 1887, p. 427). By interference of beams of light, reflected and transmitted by a plate of plane parallel optical glass, and then reflected back by two mirrors appropriately placed, fringes are caught in an observing telescope. One of the mirrors is movable in front of a micrometer screw, whose motion causes these fringes to move across the telescopic field. If the light be absolutely homogeneous, the determination consists in measurement of the distance through which the movable mirror is pushed parallel to itself and the counting of the number of fringes which pass a given point in

the field of view. According to the theory of interference the difference of path between the distances from one face of the plate to the two mirrors should be small; beyond a certain limit interference phenomena vanish, and this limit is smaller in proportion as the light is more complex. In the case of approximately homogeneous light there are periodic variations of distinctness in the fringes. For example, assume sodium light, which in the spectroscope is manifested as a pair of yellow lines near together. In the refractometer there are two sets of interference fringes, one due to each of the two slightly different wave lengths. When the difference of path is very small, or nearly the same for both of these radiation systems, the fringes coincide. The wave length for one is about one thousandth less than that for the other. If the difference of path is about five hundred waves, the maximum of brightness for one system falls on a minimum of brightness for the other, and the fringes become faint. They become again bright when the difference of path reaches a thousand wave lengths. The case is entirely similar to the familiar production of beats by a pair of slightly mistuned forks.

The method of interference thus furnishes through optical beats a means of detecting radiation differences too minute for resolution by ordinary spectroscopic methods. Spectrum lines are found to be double or multiple when all other means of resolving them fail; and the difficulty of attaining truly homogeneous light is far greater than was a few years ago supposed. By the new method it becomes possible to map out the relative intensities of the components of a multiple line, their distance apart, and even the variations of intensity within what has for convenience been called a single component. Each of the two sodium lines is itself a double whose components are separated by an interval about one-hundredth of that between the long-known main components; and an interval yet less than one-fifth of this has been detected between some of the components of the green line of mercury. Indeed Michelson deems it quite possible to detect a variation of wave length corresponding to as little as one ten-thousandth of the interval between the two main sodium lines (Astronomy and Astrophysics, p. 100, February 1894).

This new-found complexity of radiation, previously thought to be approximately if not quite simple, proved to be a temporary barrier to the accomplishment of the plan of using a light wave as a standard of length. It necessitated careful study of all those chemical elements which give bright lines that had been supposed to be simple. The red line of cadmium has been found the simplest of all those yet examined. The vapor in a rarefied state is held in a vacuum tube through which the electric spark is passed, and under this condition the difference of path for the interfering beams in the refractometer may be a number of centimeters. A short intermediate standard, furnished with a mirror at each end, is now introduced into the comparer, and moved by means

of the micrometer screw. Its length is thus measured in terms of the cadmium wave length. A series of intermediate standards, of which the second is double the first, the third double the second, etc., are thus compared, and finally in this way the value of the meter is reached.

The feasibility of this ingenious method having been made apparent, Michelson was honored with an invitation from the International Bureau of Weights and Measures to carry out the measurement at the observatory near Paris, with the collaboration of the director, M. Benoît. After many months of labor, results of extraordinary accuracy were attained. For the red line of cadmium at an air temperature of 15° C. and pressure of 760 mm., two wholly independent determinations were made. From the first a meter was found equal to 1,553,162.7 wave lengths; from the second, 1,553,164.3 wave lengths, giving a mean of 1,553,163.5 the deviation of each result from the mean being very nearly one part in two millions ("Travaux et Mémoires du Bureau Internationale des Poids et Mésures," Tome XI, p. 84, 1894). A determination by Benoît from the first series gave 1,553,163.6, which differs but one-tenth of a wave length from the mean of Michelson's measurements.

The direct comparison of the lengths of two meter bars, though not easy, is a simple operation in comparison with the indirect method just described, but does not surpass it in accuracy. Everyone knows that the meter is not an exact submultiple of the earth's circumference, and that the determination of its exact value from the seconds pendulum is full of difficulty. It may perhaps be said that the optical method is no more absolute than the pendulum method, for no human measurements can be free from error; that there is no possibility of the destruction of the original meter and all certified copies of it; and that there is no proof or probability that molecular changes are gradually producing modifications in standards of length. Even if we should grant that for all practical purposes the labor of determining the meter in terms of an unchanging optical standard has been unnecessary, the achievement is a signal scientific triumph that ranks with the brilliant work of Arago, Fresnel, and Regnault. In preparation for it much new truth has been elicited, and light waves have been shown to carry possibilities of application that Fresnel never suspected.

The physicist is nearly powerless without the aid of those who possess the highest order of mechanical skill. The interferential comparer could never have been utilized for such work as Michelson has done with it, had not Brashear made its optical parts with such an approach to perfection that no error so great as one-twentieth of a wave length could be found upon the reflecting surfaces ("Travaux et Mémoires du Bureau Internationale des Poids et Mésures," Tome XI, p. 5, 1895). In the conception, mechanical design, and execution the entire work has been distinctly American.

The interferential refractometer has been used with much skill by Hallwachs (Wiedemann's Annalen, Band 47, p. 380, and Band 53, p. 1)

for comparing the variation of refractive index of dilute solutions with variation of concentration. The fact of solution brings about a change of molecular constitution, affecting both the electric conductivity and the refractive index; and the changes in optical density are measurable in terms of the number of interference fringes which cross the field of view for a given variation of dilution.

LUMINESCENCE.

While all work on the visible spectrum is confessedly optical, we can no longer make an arbitrary division point, and declare that one part of the spectrum belongs to the domain of optics and the other not. Since the days of Brewster and the elder Becquerel fluorescent solutions have enabled us to bring within the domain of optics many wave lengths that were previously invisible. Stokes's explanation of this, as a degradation of energy quite analogous to the radiation of heat from a surface on which sunlight is shining, has been generally accepted. But whether the phenomena of fluorescence and phosphorescence are in general physical or chemical, has for the most part remained unknown, or at least very uncertain. E. Wiedemann, who suggested the term luminescence to include all such phenomena, published in 1895 (Annalen der Physik und Chemie, p. 604, April, 1895), in conjunction with Schmidt, a part of the outcome of an extended investigation undertaken with a view to clearing up these uncertainties. He has shown that it is often possible to distinguish between cases in which the emission of light springs from physical processes and those in which it is due to chemical action, or at least invariably accompanied by this. We have here, as in photography, a transformation of radiant into chemical energy, to which is superadded the retransformation of chemical into radiant energy of longer period, and this either at the same time or long after the action of the exciting rays. Indeed, between this process and that of photography in colors, the analogy is quite striking. What has generally been called phosphorescence is well known to be the effect of oxidation in the case of phosphorus itself and in that of decaying wood or other organic matter, which under certain conditions shines in the dark.

Wiedemann has shown that the shining of Balmain's luminous paint, and generally of the sulphides of the alkaline earths, is accompanied with chemical action. A long period of luminosity after the removal of the source renders highly probable the existence of what he now calls chemi-luminescence. A large number of substances, both inorganic and organic, have been examined both by direct action of light and by the action of cathode rays in a controllable vacuum tube through which sparks from a powerful electric influence machine were passed. Careful examination with appropriate reagents before and after exposure was sufficient to determine whether any chemical change had been produced. Thus the neutral chlorides of sodium and potas-

sium, after being rendered luminous by action of cathode rays, are thereby reduced to the condition of subchloride, so as to give a distinctly alkaline reaction.

Many substances, moreover, which manifest no luminescence at ordinary temperatures after exposure, or which do so for only a short time, become distinctly luminescent when warmed. This striking phenomenon is sufficient to warrant the use of a special name, thermoluminescence. Among such substances may be named the well-known sulphides of the alkaline earths, the haloid salts of the alkali metals, a series of salts of the zinc and alkaline earth groups, various compounds with aluminium, and various kinds of glass. Some of these after exposure give intense colors when heated, even after the lapse of days or weeks. That the vibratory motion corresponding to the absorption of luminous energy should maintain itself for so long a time as a mere physical process is highly improbable if not unparalleled. That it should become locked in, to be subsequently evoked by warming, certainly indicates the storing of chemical energy, just as the storage battery constitutes a chemical accumulator of electrical energy. Other indications that luminescence is as much a chemical as a physical phenomenon are found in the fact that the sudden solution of certain substances is accompanied by the manifestation of light, if they have been previously subjected to luminous radiation, but not otherwise; that alteration of color is brought about by such exposure; and that friction or crushing may cause momentary shining in such bodies as sugar. There is no conclusive direct evidence thus far that such luminescence as vanishes instantly upon the withdrawal of light is accompanied by chemical action. But Becquerel demonstrated long ago with his phosphoroscope that there is a measurable duration of luminous effect when to the unaided eye the disappearance seems instantaneous (Becquerel, Comptes rendus 96–121). Wiedemann now shows that when this duration is considerable there is generally chemical change. Since duration is only a relative term it seems highly probable that even cases of instantaneous luminescence, commonly called fluorescence, are accompanied with chemical action on a very minute scale, and that all luminescence is therefore jointly physical and chemical in character. We have thus color evoked by the direct action of light, which disturbs the atomic equilibrium that existed before exposure, and the manifestation of such color continues only until the cessation of the chemical action thus brought into play.

The influence of very low temperature upon luminescence and photographic action has been studied by Dewar (Chemical News, LXX, p. 252, 1894). The effect of light upon a photographic plate at the temperature of liquid air $-180°$ C. is reduced to only a fifth of what it is at ordinary temperature; and at $-200°$ the reduction is still greater, while all other kinds of chemical action cease. In like manner, at $-80°$ calcium sulphide ceases to be luminescent; but, if illuminated at this

low temperature and then warmed, it gives out light. At the temperature of liquid air many substances manifest luminescence which ordinarily seem almost incapable of it; such are gelatine, ivory, and even pure water. A crystal of ammonium platinocyanide, on the other hand, when immersed in liquid air and illuminated by the electric light, shines faintly when this is withdrawn. If now the liquid air be poured off so that the crystal rises rapidly in temperature, it glows brightly.

LUMINESCENCE AND PHOTOGRAPHY.

Photography, like luminescence, is a manifestation of the transformation of energy, most frequently of initial short wave length. The production of color by photography is nothing new. It was noticed by Seebeck nearly a century ago that silver chloride becomes tinted by exposure to ordinary light, with accompanying chemical change; that if then subjected a long time to red light it assumes a dull red hue, or a dull bluish hue if held in blue light. It is likewise possible by proper selection of luminescent salts to produce a selected series of tints during and after exposure to those rays which are most effective in photography. But such colors can not be made fixed and permanent. The problem of securing on the photographic plate a faithful and lasting reproduction of the various tints of a spectrum thrown upon it has baffled most of those who grappled with this subject. That it has been fully and quite satisfactorily solved can not yet be affirmed, but the last few years have brought a far nearer approach to success than an equal number of decades previously. Viewed from the scientific standpoint the goal has certainly been touched, even if commercial demands are still made in vain.

STATIONARY LIGHT WAVES.

Two quite different methods are to be considered in tracing the recent development of this interesting application of optical principles. The first is originally due to Becquerel (Am. de Chimie et de Physique (3), p. 451, 1848), but lately, in the hands of Lippmann, it has been improved and brought much nearer to success than by its originator. It depends upon the production of stationary waves of light. Every one is familiar with the formation of stationary waves upon an elastic stretched cord, and with the acoustic exhibition of stationary air waves in a closed tube by Kundt's method of light powders. That similar loops and nodes must be produced under proper conditions by interference of waves of light would appear obviously possible: and so long ago as 1868 Dr. Zenker ("Lehrbuch der Photochromie," Berlin, 1868) of Berlin explained the photographic reproduction of color, so far as it had then been accomplished, by reference to stationary light waves. But no definite proof of their production has been brought forward. A few years ago

Hertz demonstrated objectively the electromagnetic waves whose existence had been foretold by Maxwell's genius; and with suitable apparatus stationary electric waves are now almost as readily made evident as are those of sound. Hertz's brilliant success stimulated his fellow countryman, Otto Wiener, to undertake the apparently hopeless task of producing and studying stationary light waves. Wiener's admirable work (Wiedemann's Annalen, Band XL, 1890, p. 203) excited great interest on the continent of Europe, but it has been singularly neglected in England and America. It is worth much more than a passing notice.

Assume a plane silvered mirror upon which a bundle of rays of monochromatic light fall normally so as to be reflected back upon its own path. The superposition of reflected and direct waves causes a system of stationary waves, but under ordinary conditions these are wholly imperceptible. The nodes are formed upon a series of planes obviously parallel to the reflecting plane at successive distances of a half wave length. If now we consider a plane oblique to the mirror, it will cut these successive nodal planes in parallel lines, whose distance apart will be greater in proportion as the oblique plane approaches parallelism to the mirror. Although a half wave length of violet light is only one five-thousandth of a millimeter, it is easy to conceive of the cutting plane forming so small an angle with the mirror that the distance between the parallel nodal lines shall be a thousand times a half wave length. Such would be the case if the inclination of the cutting plane is reduced to a little less than four minutes of arc. The nodal lines would be one-fifth of a millimeter apart, and readily capable of resolution if their presence can be manifested at all. Imagine a very thin transparent photographic film to be stretched along the oblique cutting plane, and developed after exposure to violet light as nearly monochromatic as possible. Then the developed negative should present a succession of parallel clear and dark lines, corresponding to nodal and antinodal bands along the oblique plane, the photographic effect being annihilated along an optical nodal line.

The realization of a photographic film thin enough for such an experiment is quite conceivable when we remember that under the hammer gold is beaten into leaves so delicate that 8,000 of them would be required to make a pile 1 millimeter thick. By electrochemical deposit, Outerbridge (Journal of the Franklin Institute, Vol. CIII, p. 284, 1877) has made films of gold whose thickness is only one-hundred-thousandth of a millimeter, or one-sixtieth of a wave length of sodium light. Wiener obtained a perfectly transparent silver chloride film of collodion, whose thickness was about one-thirtieth of a wave length of sodium light. This was formed on a plate of glass and inclined at a very small angle to a plane silvered mirror which served as reflector. From an electric arc lamp the light was sent through an appropriate slit and prism, so that a selected spectral band of violet fell normally on the prepared plate in the dark room. The developed

negative presented the alternate bands, in perfectly regular order, more than a half millimeter apart. Various tests were applied to guard against error in interpretation, and the existence of such stationary waves was proved beyond all doubt.

These waves, moreover, when polarized light was employed, furnished the means of determining the direction of vibration with relation to the plane in which the light is most copiously reflected when incident at the polarizing angle, and thus of subjecting to experiment the question as to whether the plane of vibration is coincident with this plane of polarization or is perpendicular to it. The former of these views was held by Neumann and MacCullagh, the latter by Fresnel. Let a beam of polarized light fall upon the mirror at an angle of about 45°. If the vibrations in the incident beam are parallel to the mirror, and hence perpendicular to the plane of polarization, those of the reflected and incident beams will be parallel to each other, and hence capable of interference. But if the vibrations of the incident beams are in a plane identical with that of incidence, and hence in the plane of polarization, the vibrations of incident and reflected beams are in mutually perpendicular planes, and hence can not interfere. Wiener obtained interference fringes when the light was polarized in the plane of incidence, while the polarized in the plane perpendicular to this gave no trace of interference. The theory of Fresnel was thus confirmed experimentally. Again, the familiar phenomenon of Newton's rings shows us that on changing media there is a change of phase of the incident light, else the central spot where the two surfaces come into optical contact would be white instead of black. But there has been difference of opinion as to whether this change of phase occurs at the upper surface of the air film, where the light passes from glass to less dense air, or at the lower surface, where it passes from air to more dense glass. In the latter event, there should be a node at the reflecting surface. Replacing the silvered plane surface by a lens in contact with the photographic film, Wiener obtained circular fringes with no photographic action, at the center, showing the nodal point to be at the point of contact, and thus again confirming the theory of Fresnel.

COLOR PHOTOGRAPHY.

The conditions being now specified under which stationary light waves are produced, let us imagine common instead of monochromatic light to be transmitted normally through a transparent sensitive film. Then a variety of stationary interference planes are produced. This is the underlying principle of the process employed by Lippmann in Paris, who, in 1892 (Comptes rendus, Tome CXIV, p. 961, and Tome CXV, p. 575), succeeded in obtaining a photograph of the solar spectrum in natural colors. Upon a surface backed with a reflecting mirror of mercury is a silver bromide albumen film, which has been treated with one or more aniline dyes to render it equally sensitive to waves of

long and short period. After exposure and development the natural colors are manifested with brilliancy. Apart from the fundamental principle already expressed, it can scarcely be said that the rationale of the process has yet been very fully and clearly explained. Lippmann recognizes the stationary wave systems, with maxima and minima of brightness in the film and corresponding maxima and minima of silver deposit. If the incident light is homogeneous, a series of equidistant parallel planes of equal photographic efficiency are produced in the film. If the plate after development is illuminated with white light, then to every point within the film there comes from below a certain amount of reflected energy which is a continuous periodic function of the distance from the reflecting surface. The total reflected light of any color becomes then represented by the integral of this periodic function for the entire thickness of the layer. The solution of this integral brings the result that the intensity of the reflected light decreases with increasing thickness of the layer, approaching zero as a limit, so long as this light is of different wave length from the homogeneous light employed for illumination of the plate. Only light of the same wave length, or of an entire multiple of this, maintains a finite value. A similar consideration applies to each of the hues composing white light. By such mathematical considerations, Lippmann (Journal de Physique, p. 97, 1894) reaches the conclusion that the light reflected from the plate must have exactly the same relations of wave length as that with which the plate was illuminated.

For the Lippmann photographs, which at first required a very long exposure, and could even then be satisfactorily viewed at only a single definite angle, it is now claimed that an exposure of only a few seconds is needed, and that the colors are visible at all angles of incidence so long as the plate is moist (Journal de Physique, p. 84, 1894). But, like the daguerreotypes of fifty years ago, they are incapable of multiplication, and, great as is the scientific interest connected with them, it seems scarcely probable that they can long continue to hold an important place practically. The problem of ascertaining definitely the cause of the return of a color the same as that which falls upon a given surface may seem to be solved mathematically, but the mastery of the physical conditions required to produce a single colored negative, from which may be had any desired number of positives with varied hues accurately reproduced, is still in the future. From the very nature of stationary light waves it does not appear probable that the Becquerel method as improved by Lippmann will give the means of multiplying copies of a single picture. Wiener has lately published an elaborate research upon this subject (O. Wiener, Wiedemann's Annalen, pp. 225–281, June, 1895), in which he recognizes the necessity for the employment not of interference colors but rather of what he calls body colors (Körperfarben) due to chemical modification of the reflecting surface. M. Carey Lea (American Journal of Science, p. 349, May 1887), in 1887

obtained a rose-colored form of silver photochloride which "in the violet of the spectrum assumed a pure violet color, in the blue it acquired a slate blue, in green and yellow a bleaching influence was shown, in the red it remained unchanged." But in the absence of any means of fixing these colors, a promising prospect brings disappointment.

While it is abundantly possible that colored illumination upon suitable color-receptive materials can give rise to similar body colors, we are still far from having these materials under control. There seems at present to be greater promise in another and quite different application of optical principles. The suggestion appears to have been first named by Maxwell (Royal Institution lecture, May 17, 1861) in 1861 that photography in colors would be possible if sensitizing substances were discovered, each sensitive to only a single primary color.

Three negatives might be obtained, one in each color; and three complementary positives from these, when superposed and carefully adjusted, would present a combination that includes all the colors of nature. In 1873 H. W. Vogel in Berlin discovered that silver bromide, by treatment with certain aniline dyes, notably eosine and cyanine blue, can be made sensitive to waves of much longer period than those hitherto effective in photography. In 1885 he proposed to sensitize plates for each of a number of successive regions in the spectrum, and to make as many complementary pigment prints as negatives, which should then be superimposed. This somewhat complicated plan proved difficult in practice. In 1888 F. E. Ives (Journal of the Franklin Institute, January, 1889), of Philadelphia, adopting the more simple Helmholtz-Maxwell modification of Young's theory of color, applied it to the preparation of suitable compound color screens which were carefully adjusted to secure correspondence with Maxwell's intensity curves for the primary colors. The result was a good reproduction of the solar spectrum. But to reproduce the compound hues of nature it is necessary specially to recognize the fact that although the spectrum is made up of an infinite number of successive hues, the three color sensations in the eye are most powerfully excited by combinations rather than by simple spectral hues. Thus, according to Maxwell's curves, the sensation of red is excited more strongly by the orange rays than by the brightest red rays, but the green sensation is excited at the same time. This fact has to be applied in the preparation of the negatives, while images or prints from these must be made with colors that represent only the primary color sensations. Properly selected color screens must, therefore, be used for transmission of light to plates sensitized with suitable aniline dyes, and the adjustment of ratios with this end in view is not easy; but it has been successfully accomplished. From three negatives thus made, each in its proper tint, positives are secured; and these are projected, each through its appropriate color screen, to the same area upon a white screen. The addition of lights thus sent from the triple lantern gives the original tints with great fidelity.

Mr. Ives has devised a special form of camera by which the three elementary negatives are taken simultaneously, and also an instrument, the photochromoscope, in which a system of mirrors and lenses brings to the eye a combination similar to that projected with the triple lantern. A double instrument of this kind forms the most perfect type of stereoscope, bringing out with great vividness from the prepared stereographs the combined effect of color, form, and binocular perspective. It is only within the past year that these improvements have been perfected. By further application of the same principles, Mr. Ives has produced permanent colored prints on glass, which do not require to be examined by the aid of any instrument. Each of these negatives is made with a colored screen which transmits tints complementary to those which it is desired to reproduce. The three gelatine films are soaked in aniline dyes of suitable tint and superimposed between plates of glass. When viewed as a transparency, such a print gives a faithful reproduction of the natural colors.

The problem of color reproduction is thus solved, not indeed so simply, but more effectively, than by the method of interference of light, or by those body-color methods that have thus far been applied. To the imaginative enthusiasts who are fond of repeating the once novel information that "electricity is still in its infancy," it may be a source of equal delight to believe that photography in colors, a yet more delicate infant, is soon to take the place of that photography in light and shade with which most of us have had to content ourselves thus far; but so long as an instrument is needed to help in viewing chromograms, the popular appreciation of these will be limited. We may take a lesson from the history of the stereoscope. Yet it is gratifying to recognize the great impetus that this beautiful art has received during the last few years. We may quite reasonably expect that the best is yet to come, and that it will have an important place among the future applications of optical science.

THE INFRA-RED SPECTRUM.

Among the splendid optical discoveries of this century, probably the most prominent are photography and spectrum analysis, each belonging jointly to optics and chemistry. Photography was at first supposed to be concerned only with the most refrangible rays of the spectrum, but Abney and Rowland have photographed considerably below the visible red. Beyond the range thus attained qualitative knowledge was secured by Herschel, Becquerel, Draper, Melloni, Müller, Tyndall, Lamansky, and Mouton. But our quantitative knowledge of this region began with the invention and use of the bolometer by Langley ("Selective absorption of solar energy," Am. Journal of Science, March, 1883, p. 169), whose solar energy curve has been familiar to all physicists during the last dozen years. During this interval the bolometer has been used with signal success by Ångström, Rubens, Snow, and

Paschen, who have made improvements not only in the instrument itself but in the delicacy of its necessary accompaniment, the galvanometer. The work of Snow (Physical Review, Vol. I. pp. 28 and 95), particularly, on the infra-red spectra of the voltaic arc and of the alkalies, and that done by him in conjunction with Rubens (Astronomy and Astrophysics, March, 1893, p. 231), on refraction through rock salt, sylvite, and fluorite, exhibited the capacities of the bolometer even better perhaps than Langley's previous work on the sun. But more recently with the collaboration of several able assistants, and more particularly the great ingenuity and mechanical skill of Wadsworth, the sensitiveness of Langley's galvanometer has been so exalted, and the bolometer connected in such manner with photographic apparatus as to make it an automatically controlled system, by which an hour's work now brings results superior in both quantity and quality to what formerly required many weeks or even months (Langley, "On recent researches in the infra-red spectrum:" Report of Oxford meeting of British Association, 1894). Not only is an entire solar energy curve now easily obtained in a single day, but even a succession of them. It becomes thus possible by comparison to eliminate the effect of temporary disturbing conditions, and to combine results in such a way as to represent the infra-red cold bands almost as accurately as the absorption lines of the visible spectrum are indicated by use of the diffraction grating. It will undoubtedly become possible to determine in large measure to what extent these bands are due to atmospheric absorption, and which of them are produced by absorption outside of the earth's atmosphere.

With the diffraction grating, supplemented by the radiomicrometer, Percival Lewis (Astrophysical Journal, June, 1895, p. 1, and August, 1895, p. 106), has recently investigated the infra-red spectra of sodium, lithium, thallium, strontium, calcium, and silver, attaining results which accord well with the best previously attained by those who had employed the bolometer, and which demonstrate the exceeding delicacy of the radiomicrometer as an instrument of research.

THE VISIBLE SPECTRUM.

To follow out all the applications of the spectroscope that have resulted in recent additions to our knowledge would carry us far beyond the scope of a single paper. It is possible only to make brief mention of a few.

For a number of years Rowland (ibid., January to August 1895) has been investigating the spectra of all the chemical elements, photographing them in connection with the normal solar spectrum, and reducing them to his table of standards, which is now accepted everywhere. The work is of such magnitude that years more must elapse before its completion. It now includes all wave lengths from 3,722 to 7,200, and of these the list already published extends as far as wave lengths 5,150, or from ultra violet nearly to the middle of the green.

Through the spectroscope chiefly has been established during the present year the discovery of the new atmospheric element, argon, by Lord Rayleigh and Professor Ramsay (Proc. Royal Society, January 31, 1895)[1]; its remarkable property of green fluorescence when the electric spark is passed through it in presence of benzine, by Berthelot and Deslandres (Comptes rendus, June 24, 1895); and its association in meteoric iron and various minerals with helium, now proved to be a terrestrial as well as solar element, by Ramsay (Nature, April 4, May 16, July 4 and 25, 1895), Crookes, Lockyer, and others.

With the diffraction spectroscope Rydberg (Wiedemann's Annalen, 1893--1894) and Kayser and Runge (ibid., 1888–1895) have discovered interesting relations among the spectral lines of a large number of terrestrial elements, arranging them into series whose distribution manifests chemical relationship quite analogous to that indicated in Mendelejeff's periodic law.

By photographing the spectrum of Saturn's rings and noting the relative displacement of the different parts of a spectral line, Keeler (Astrophysical Journal, May 1895, p. 416) has obtained a beautiful direct proof of the meteoric constitution of these rings, a confirmation of the hypothesis put forth by Maxwell in 1859, that the outer portion of the rings must revolve more slowly than the inner portion, and yet not satisfy the conditions of fluidity. His work has been repeated and confirmed by Campbell (ibid., August 1895, p. 127) at the Lick Observatory.

The spectroheliograph devised by Hale (Astronomy and Astrophysics, March, 1893, p. 256) has enabled him to photograph, on any bright day, not only the solar photosphere and spots, but also the chromosphere and protuberances. He has made some remarkable attempts with this instrument to photograph the corona without an eclipse, unsuccessfully thus far, but not without promise of future success.

POLARIZED LIGHT.

In the domain of polarized light, there have been several noteworthy recent researches. Nichols and Snow (Philosophical Magazine (5), Vol. XXXIII, p. 379) have shown that calcite, though readily transparent for the brighter rays of the spectrum, rapidly diminishes in power of transmission for waves of short period, so that for the extreme violet this power is scarcely half so great as for the yellow. The transmissive power of this crystal for the infra-red rays, between the wave-length limits of 1 micron and 5.5 microns, has been investigated with the bolometer by Merritt (Physical Review, May-June 1895, p. 424), who reaches the interesting result that the transmission curve for

[1] See also Smithsonian Contributions to Knowledge, Vol. XXIX, where is published the original memoir announcing the discovery of argon, for which Lord Rayleigh and Professor Ramsay were awarded the first prize of $10,000, in the Hodgkins Fund Prize competition of the Smithsonian Institution.—EDITOR.

the ordinary ray is wholly independent of that for the extraordinary, the absorption being in general much greater for the former. Several sharp absorption bands are found for each ray. For radiations whose wave-length exceeds 3.2 microns, the absorption of the ordinary ray is almost complete, so that calcite behaves for such radiation just as tourmaline does for the rays of the visible spectrum. The independence of the two transmission curves is found to exist also for quartz and tourmaline, these curves for the latter crossing each other twice in the infra-red region.

The application of polarized light to the investigation of internal stress in transparent media was made more than forty years ago by Wertheim (Comptes rendus, 32, p. 289, 1851), who demonstrated that the retardation of the rays is proportional to the load. An extended series of such experiments has been lately made in America by Marston (Physical Review, September, October, p. 127, 1893), who, besides confirming Wertheim's conclusion, shows that, "for small strains at least, the colors seen in a strained glass body, when polarized light is passed through it in a direction parallel to one of the axes of strain, are measured by the algebraic difference of the intensities of those two principal strains whose directions are perpendicular to the direction of the polarized light."

A new substance with double rotatory power, like quartz, has been discovered by Wyrouboff (Journal de Physique (3), 3, 452, 1894), the neutral anhydrous tartrate of rubidium, which is unique in one respect. The rotatory power of the substance in the crystalline state becomes reversed in solution. This wholly new phenomenon introduces some perplexity in connection with certain molecular theories that have been formulated to account for double rotatory power.

Crehore (Transactions of the American Institute of Electrical Engineers, October, 1894, p. 91) has ingeniously applied Faraday's principle of electro-magnetic rotation of the plane of polarization in carbon bisulphide to the photographing of alternate current curves. Every variation in the magnetic field causes variation in the amount of light transmitted through a pair of crossed Nicol prisms. The combination becomes a chronograph with an index as free from inertia as the beam reflected from a galvanometer mirror. The same instrument has been applied to measurement of the velocity of projectiles (Journal of the United States Artillery, p. 409, July, 1895), with results of exceeding interest to the student of gunnery.

PHYSIOLOGICAL OPTICS.

The temptation to dilate upon recent progress in physiological optics has to be resisted. The revision of Helmholtz's great book on this subject was interrupted by the death of the distinguished author, but the last part is now approaching completion under the care of his pupil, Arthur König, who, in connection with Diederici, has done

much important work in this domain. The selection of hues for the three primary color sensations has been slightly modified. Young selected the two extremes of the spectrum, red and violet, together with green, which is about midway between them. The hues now accepted by Helmholtz and those who follow his lead, including the great majority of physicists, are a highly saturated carmine red, an equally saturated ultramarine blue, and a yellowish green, corresponding somewhat to that of vegetation. The red and blue agree with those previously determined by Hering, but the rivalry between the two schools on the subject of color sensation continues, and perhaps will last through a period commensurate with the difficulty of devising crucial experiments.

Independent theories of color sensation have been brought out by Mrs. Franklin (Christine Ladd Franklin, "Eine neue Theorie der Lichtempfundungen," Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 1892), in America, and by Ebbinghaus ("Theorie des Farbensehens," ibid., 1893), in Germany. The former particularly is worthy of much more extended notice than can here be given. It may perhaps be quite properly called a chemical theory of vision. Light is always bringing about chemical changes in external objects, and the eye is the one organ whose exercise requires the action of light, while such chemical action is implied in the performance of most of the bodily functions, such as the assimilation of food and the oxidation of the blood. The bleaching action of light upon the visual purple, which is continually formed on the retina, has been known ever since the discovery of this in 1877 by Kühne, who secured evanescent retinal photographs in the eyes of rabbits. Mrs. Franklin considers that light sensation is the outcome of photochemical dissociation of two kinds of retinal molecules that she denominates gray molecules and color molecules, of which the latter arise from the gray molecules by differentiation in such a way that the atoms of the outer layer group themselves differently in three directions, and the corresponding action of light of proper wave length gives rise to the three fundamental color sensations. She develops the theory with much skill, applying it particularly to the phenomena of retinal fatigue and color blindness. To the objection that there is no direct proof of the existence of the assumed gray and color molecules, it may be answered that Helmholtz himself fully recognized the uncertainty of the assumption that three different sets of nerves respond to the three fundamental color sensations, and he admitted that these may be only different activities in the same retinal cone. The supposition of three adjacent cones, responding respectively to the three fundamental sensations, is made only for the sake of greater convenience in discussion.

Indeed, there is still much for us to learn regarding the nature of color sensation. Among the yet unexplained phenomena are those of simultaneous color contrast. The fact that a small brightly colored

area on a gray background appears surrounded by its complementary tint is familiar enough. For its explanation it has been common to assume that there is unconscious motion of the observer's eyes, incipient retinal fatigue, an error of judgment, or fluctuation of judgment. This has been tested by A. M. Mayer (American Journal of Science, July, 1893), who ingeniously devised methods for showing these contrast phenomena on surfaces large enough to match the colors with those of rotating color disks, and thus to arrive at quantitative statements of their hues. When viewed through a small opening in a revolving disk, the subjective contrast color was unmistakably perceptible when the duration of passage of the opening was less than one-thousandth of a second. The same effect was obtained in a dark room with instantaneous illumination of the colored surface by the strong spark of an electric influence machine. The duration of illumination is thus almost infinitesimal, certainly not more than one ten-millionth of a second. The hypothesis of fluctuation of judgment is thus shown to be wholly untenable. I have performed most of these experiments, either with Professor Mayer or separately, and my testimony can therefore be united with his. The case is quite analogous to that of the perception of binocular relief, which was once explained as the product of a judgment, but was found to be always possible with instantaneous illumination. Professor Mayer has devised a disk photometer based on color contrast, with which the error of a single reading was found much less than with the Bunsen photometer.

The rotating color disk has been applied by O. N. Rood (American Journal of Science, September, 1893) to the determination of luminosity independently of color, by taking advantage of the flickering appearance on a rotating disk upon which two parts have different reflecting powers. An extreme case of this is that of a white sector upon a black disk. At a certain critical speed the retinal shock due to momentary impression by white light becomes analyzed into the subjective impression of spectral colors, the duration of the retinal sensation varying with the wave length of the incident light. The law of this variation has been studied by Plateau ("Dissertation sur quelques propriétés des impressions produits par la lumière sur l'organe de la vue," Liege, 1829), Nichols (American Journal of Science, October, 1884), and more recently with much precision by Ferry (ibid., September, 1892), who showed that retinal persistence varies inversely as the logarithm of the luminosity. For a given source of light separated into its spectral components, the yellow is the brightest. For this hue accordingly the retinal impression is shortest, and for violet it is longest.

Under appropriate conditions the after-effect on the retina has a certain pulsatory character, as first noted by C. A. Young (Philosophical Magazine, Vol. XLIII, p. 343, 1872) in 1872, and carefully studied within the last few years by Charpentier ("Oscillations rétiniennes," Comptes rendus, Vol. CXIII, p. 147, 1891) in France, and Shelford

Bidwell ("On the recurrent images following visual impressions," Proc. Royal Society, March 27, 1894) in England. A disk with properly arranged black and white sectors, if brightly illuminated and looked at while revolving at a moderate rate, becomes apparently colored, just as a momentary glance at the sun causes the perception of a succession of subjective spectral hues which may last a number of seconds. The phenomenon in relation to the disk was known as early as 1838 (Fechner, Poggendorff's Annalen, 1838), and explained by Rood (American Journal of Science, September, 1860) in 1860. The rediscovery of what has been long forgotten arouses all the interest of novelty. The "artificial spectrum top," devised by Benham (Nature, November 29, 1894, p. 113) last autumn, excited interest on two continents, and was promptly copyrighted by a prominent firm of opticians (ibid., March 14, 1895, p. 463) in England. It would perhaps be equally enterprising to copyright the solar spectrum.

The limits of a single address forbid my touching upon the large and practically important subject of color blindness. Indeed, in both physical and physiological optics much has been omitted that is abundantly worthy of attention. In behalf of my hearers it may be wise to take heed, once more, of the fate of Tarpeia, who was overwhelmed with the abundance of her reward.

AIR AND LIFE.

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[Translation (by the author) of the essay on L'Air et la Vie, submitted by Dr. Henry de Varigny in the Hodgkins Fund Prize Competition of the Smithsonian Institution, and awarded "the third prize of $1,000, for the best popular treatise upon atmospheric air, its properties and relationships."]

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INTRODUCTION.

A great chemist, J. B. Dumas, once said that living organisms are nothing but "condensed air." He thus expressed, in terse terms, the result of the investigations pursued by himself and others into the relations of the atmosphere to living beings.

My purpose, in the following pages, is to show how closely Dumas's statement agrees with ascertained facts, even more closely than he himself supposed. It is also desirable to briefly instance and illustrate the varied ways in which air influences the general life of the globe. If the ordinary definition of the word were not an impediment to its use in the present case, I would say that I purpose making a general sketch of the "biology" of the atmosphere. More exactly and appropriately I may use a quite similar term, and say that the subject-matter of this essay is the "natural history" of the air—taking the term in the sense given to it by Geoffroy St. Hilaire—an essay upon the properties of air considered in its relations to living beings, upon its composition, its contents, its origin, its varied modes of action.

While I shall especially and particularly consider air in its relations to life, I shall also refer briefly to its relations to other subjects, pointing out those which it would be useful to investigate further in order to increase the scope of our knowledge.

The study of the atmosphere is truly one of great magnitude; its relations to the remainder of the universe are so varied and important, the subjects which it suggests are so numerous and take us through so many fields of inquiry, that a comparison suggests itself forcibly—just as the atmosphere surrounds our whole planet and forces itself into the clefts and fissures between its elements and rocks to the depths of the soil, in the same manner does the study of air pertain to all departments of science, to geology as well as astronomy, to physics no less than to chemistry, and to biology in the largest sense of the term.

While it would be a hazardous enterprise to undertake a complete review of so important a subject, it may prove useful to give a rapid sketch of some features, and that I shall endeavor to do, by showing what air is, physically and chemically considered, what is its origin, what it contains, and of what use it is to life. Doubtless this is but a small part of the subject, but this sketch may contribute to show how vast and varied is that chapter of science that goes under the name of the "study of the atmosphere."

I.—Air Considered from the Physical Point of View.

Vast as are the proportions of the atmosphere it is none the less invisible. It surrounds us on every side; we are bathed in it, and we do not see it; when it is not in motion we do not feel it. Although having material existence and creating material effects, for evil or for good, it is immaterial to our senses. This fluid, this gas, may, however, be weighed. Jean Rey[1] and Otto von Guericke[2] were the first who gave positive proof of this, and showed that a glass receiver in which a vacuum had been made—even imperfectly—weighed less than the same receiver in normal and free connection with the surrounding atmosphere—that is, full of air—and, on the other hand, a receiver into which air is forced and maintained under pressure weighs more than the same receiver full of air at the normal pressure *pro loco et tempore.* One liter of air, pure and dry, under the pressure of 760 millimeters, at 0° temperature, and at the latitude of Paris, weighs 1.293 grams (Regnault). It weighs more if the pressure is higher, less if it is lower; and hence a liter of air has more weight at the bottom of a shaft in a mine than at sea level, and less on top of a hill or mountain. The higher the altitude at which air is weighed the less it weighs, because it expands, the same weight of air occupying a larger space or volume. Air is more dense at low stations, less dense in the higher strata of the atmosphere, so that when the weight of air is mentioned it is always given with reference to a certain altitude, to a certain pressure, and also to a certain temperature and hygrometric state, because these different conditions exert a considerable influence upon the matter.

As in the case of other gases, air is made up of molecules, and these are considered as being in a state of perpetual motion. It has been reckoned that the number of impacts or collisions to which each molecule is subjected during each second. in the tremendous turmoil which takes place in the air, amounts to something like 4,700,000,000! These molecules are exceedingly small, and Sir William Thomson (Lord Kelvin), Clerk Maxwell, and Van de Waals give their dimensions as being less than a fraction of one-millionth of a millimeter, 1 cubic centimeter of air, at 0° and 760 millimeters pressure, containing, in round numbers, some 21,000,000,000,000,000,000 of these molecules.

I have referred to the fact that the weight of the air is not the same in all localities. It also varies in the same locality. The sum total of

[1] Jean Rey, French physician and physicist, said, in 1630, that if tin is burnt in contact with air, it increases in weight, and this increase is due to air which has been absorbed by the metal during the combustion.

[2] Otto von Guericke, born 1602, died 1686. He also demonstrated atmospheric pressure by means of the instrument called the Magdeburg hemispheres—two hollow hemispherical cups which it is very difficult to separate when a vacuum has been created in the interior.

the weight of the atmosphere, wherever considered, varies every day more or less, often appreciably within the limits of a few hours and even minutes. This could not happen, of course, if the weight of the strata of air did not vary also. The weight of the whole atmosphere increases or decreases because the weight of the air, considered at any region vertically above the point where the observation is made, increases or decreases. These variations of weight, or pressure, are indicated by the barometer—devised in 1643 by Torricelli, pupil and friend of Galileo—and the oscillations of that instrument are only indications of the differences of the weight or pressure of the air.

Now, as the pressure is increased at low stations, and diminished at high ones, and, as there is a very definite and regular connection between differences of altitude and barometrical indications, it is conceivable that the barometer may, to some extent, and with certain limitations, yield information as to the altitude at which an observer finds himself. It is sufficient to mention the fact; the methods by which it is established would require too long an exposition.

Since air is material and has a weight of its own, however variable, it must press upon all organisms. It is not difficult to estimate with some precision the weight of the superincumbent air. For each square centimeter of our skin, the pressure exerted is exactly that of a vertical column of mercury 1 square centimeter in section, and of the same height as the barometrical column at that moment. If the barometer stands at 760 millimeters, the pressure is exactly that of 76 cubic centimeters of mercury, and as each cubic centimeter weighs 13.6 grams, the sum total, per square centimeter, is 1 kilogram 33 grams, or about 15 pounds per square inch. Taking the skin surface of the average adult to be something like 1½ square meters (15,000 square centimeters), the weight with which the atmosphere presses on each of us amounts to 15,450 kilograms; but under ordinary circumstances we do not feel this enormous load, because the pressure is exerted in all directions; from within outward as well as from without inward, from below upward as well as from above downward. To perceive this pressure, it must be removed from one side, as when the hand is placed over the open end of a cylinder in which a vacuum is being formed; then one feels the strong pressure pushing the hand toward the opposite end of the cylinder. Of course the pressure exerted upon the body and all objects, is lessened as the altitude increases, or the barometer falls; and, reciprocally, if the barometer rises, or if the body be at a low station—in a mine for instance—the pressure is higher. The total weight of the atmosphere, at sea level, under normal circumstances, averages some 5,000,000,000,000,000,000 kilograms—that is, the millionth of the weight of our planet itself; or, to use other terms, the weight of a continuous stratum of mercury 76 centimeters high, and covering the entire surface of the globe, both sea and land. This is a fairly high figure for a

substance so nearly immaterial that it escapes our vision. However, air is not always invisible; it may be seen very clearly; it may also be touched and handled, although no one would undertake to do so, or to recommend the feat. Whilst it is gaseous under normal pressure and circumstances, it may be made to assume the liquid form when subjected simultaneously to the influence of considerable cold and very high pressure. High pressure alone is not sufficient. Under a pressure of 3,000 atmospheres, 3,000 times that of ordinary sea-level pressure, oxygen and nitrogen remain gases (Natterer): but if at the same time the temperature is lowered, they immediately assume the liquid condition. MM. Cailletet and Pictet have obtained liquid air by means of pressures of 300, 500, or 1,000 atmospheres cooperating with intense cold, with the cold corresponding to 100° or 200° below zero (Celsius or centigrade). Under such circumstances air may even assume the solid form: the liquid air freezes into a solid block.[1]

No one could venture to touch this liquid or solid with the bare skin, for two reasons; one being that, of course, air can be kept liquid or solid only under the circumstances of its production, and instantly becomes a gas under normal pressure or temperature: the other, that, even if the transformation were not instantaneous, the intense absorption of heat (production of cold) which accompanies the passage from the liquid or solid to the gaseous state would be more than sufficient to kill instantly all living tissues in the vicinity.

It is enough for our present purpose to simply mention the importance of air as an elastic fluid, and the part played by this gas in luminous, thermic, acoustic, and electric phenomena, where it is an all-important medium. It is also sufficient to remind the reader of the temperature of the atmosphere and its varied movements, from the light breeze that cools the hot summer days to the cyclones and tornadoes which destroy buildings and tear up the strongest giants of the forests. Lastly, the atmosphere is very far from being unlimited. It ceases at some distance from our planet, becoming very thin and rare even at altitudes that are not exceedingly great, such as 5,000 meters (Mont Blanc, 4,813 meters; Gaurisankar 8,840 meters), and while we are not prepared to state the exact distance from the earth at which all traces of air disappear, it is generally admitted that above 320 or 350 kilometers (1 kilometer=1,000 meters) height, vertically, there is no atmosphere worth mentioning. Of course, at such altitudes, the air must be exceedingly thin and rarefied, as it is in the exhausted receiver of the air pump.

It is commonly said that air is tasteless and odorless. Pure air

[1] The gas is first cooled down to 30° below zero, and then compressed under 200 or 300 atmospheres. It remains fluid; but if a small amount of it is then allowed to escape, the sudden expansion—which is accompanied by a production of cold, while compression causes heat to be evolved—cools down the remainder of the air, the temperature falls to 200° below zero, and the air immediately assumes the liquid condition. Lower down it freezes and becomes a solid block.

may be unable to affect the olfactory membrane; but this is not the case with the atmosphere generally. The air that surrounds us is full of scents and odors, but we are so accustomed to them that we take no notice thereof. But after we have spent some time in an atmosphere where most ordinary odors can not conveniently gain access, and then return to our ordinary surroundings, the case is altered, and we perceive a very powerful odor. This has been noticed by different observers after a considerable sojourn in deep caves, such as the Mammoth Cave in Kentucky. The air in these caves is nearly odorless, and when, after a few hours spent in this scentless environment, the visitor emerges again into the open, the atmosphere seems powerfully, even violently, scented or odoriferous, and some persons may even be temporarily affected by the intensity of the sensation. During the sojourn in the unscented air the olfactory cells have rested, but the renewal of their activity, generally unconscious, is accompanied by a very strong sensation which however soon fades.

The atmosphere does not stop at the surface of the seas, nor does it cease at the surface of the soil. It penetrates both, the former especially. In the latter the access of air is very soon arrested by the compactness of the rocks or strata, and, generally speaking, the proportion of air in the soil is very small in all cases where there are no clefts, fissures, or deep underground galleries. In the superficial layer, however, the case is different: air is always present in appreciable proportions in the less compact parts where plants push their roots and seek their nutriment; and in the deepest shafts, caverns, caves, and other natural or artificial excavations of the soil, air exists. It should not be expected to find there as pure a gas as that which surrounds the exterior of the planet. In the soil many slow but continuous chemical reactions are going on between the air and the solid constituents, and the result is an alteration of both sets of elements; some chemicals of the earth and rocks are transformed, and while the air loses some part of its constituents new elements are added to it, and thus its normal composition is soon altered. This is the reason why great care should always be exercised to ascertain the condition of air in all deep cavities, and even in normal excavations if they are rather secluded. The air may have been so much altered in its composition as to have become unfit for the maintenance of life, and cases are on record where it consisted almost entirely of carbonic acid. Among the investigators who have specially concerned themselves with the chemical composition of "ground" air, Boussingault has obtained interesting results, showing that while 1 cubic meter of normal atmosphere contains about 4 deciliters (or 0.216 gram) of carbon, 1 cubic meter of ground air contains 9 liters (or nearly 5 grams), which is twenty-two or twenty-three times more. In recently manured soil the proportion is much more considerable, and the amount of carbonic acid may be twenty-four times as great as in atmospheric air. This considerable amount

of carbonic acid in ground air fully explains a number of accidents, inasmuch as while the proportion of this gas is considerably increased that of oxygen is greatly diminished.

Air penetrates to a great depth in water, whether fresh or salt. This is shown by the number of living forms found, not only at the surface or in its neighborhood, but at the greatest depths to which man has yet been able to lower his nets, dredges, and sounding apparatus. Since living organisms exist in the depths of the ocean, and since they are physiologically, in their most important features, constructed on the same principles as those which live near the surface, it is obvious that in the waters of the deep, air must be dissolved of which they take advantage for their respiratory functions. Direct and precise observation fully confirms this inductive reasoning. Many instruments have been devised for the purpose of obtaining water from different depths. One of the first was the bottle, which was used by the Kiel committee. This bottle, firmly stopped and empty, was lowered to the required depth, and a sudden pull was enough to cause it to open, the surrounding water filling it in a few seconds. Many similar implements have been since invented by Bunsen, Meyer, Mill, Buchanan (*Challenger*), Ellman, Sigsbee (*Blake*), Richard, Villegente, and Paul Regnard. The description of these instruments is given at length in many works—for instance, in T. Thoulet's Océanographie (Vol. I), Paris, 1890, and P. Regnard's La vie dans les eaux, Paris, 1891—where the reader who desires full information on the matter may find it, and it will suffice for our purpose to give a general summary of the results obtained, without detailing the methods by which water is brought to the surface from different depths, or those, familiar to all, by which the gases contained in water are extracted and submitted to chemical analysis. In short, the results of these experiments fully and completely confirm the opinion above expressed, that even at the greatest depths water does contain air; that the atmosphere extends down to the nearly unfathomable abysses of the ocean.

As to rivers and lakes, or other shallow waters, the demonstration is most easy. Their water contains oxygen, nitrogen, and carbonic acid. But it is a noteworthy fact that these gases are not to be found in the proportions in which they exist in the atmosphere. Strictly speaking, one can not say that there is any air in water. What we find are the elements of air, the latter being all present, but their proportions being different from those in the normal atmosphere. For instance, 1 liter of river water contains from 4 to 8 cubic centimeters of oxygen; from 12 to 18 cubic centimeters of nitrogen, and from 2 to 20 or 25 cubic centimeters of carbonic acid. These proportions differ greatly from those which these three constituents have in normal air, and it must be noted that the variations are different in different rivers or even in the same river when examined in different places. Take the Seine River, for instance. Each liter of water contains 32.1 cubic centimeters

of gas, of which 3.9 are oxygen, 12 nitrogen, and 16.2 are carbonic acid. Take the Rhone River, on the other hand, and you find 34.8 cubic centimeters of gas, of which 8.4 are oxygen, 18.4 nitrogen, and 8 carbonic acid. These differences are less surprising after reflection. Each river may and does differ in chemical constitution from other rivers, and even from itself, at different times and places, because of the difference in the nature and quantity of the chemical operations going on in the water. The chemical composition of the banks varies, and the activity of living organisms within the waters also varies. Such differences must exert their influence upon the chemical composition of the latter, and we have abundant proof that they do so. If the water of the same river, taken at different places at the same moment, is tested chemically, differences are observed which are sometimes considerable. For instance, the Thames, above London, contains 7.4 oxygen, at Hammersmith 4.7, at Somerset House 1.5, at Woolwich 0.25. Whence arise these considerable variations? They are easily explained by the fact that the river receives a large quantity of organic débris, vegetables, dead animals, and a large number of dead or dying substances or organisms; the débris combines with oxygen, and thus the amount of this gas is greatly diminished. The consequence is that the fish often perish through asphyxia, the amount of oxygen being inadequate. The same occurs in Paris. After its passage through the city, the Seine is generally quite unfit to support the life of most aquatic animals. Many species are not to be seen in the river at Paris, nor below it for some distance, although found above, where the water is sufficiently pure and aerated, and some 10 or 20 miles below, where aeration has been sufficient to make up for the loss, the water having absorbed enough fresh oxygen from the atmosphere.

So much for one series of differences in aeration. But another series exists which is even of greater interest. The aeration of waters, or the absorption of gases by water, varies according to general external conditions, among which temperature and pressure rank highest—not only general pressure, but, so to speak, individual pressure, or, to put it in other terms, the proportion of any given gas in a mixture. Under identical conditions, each gas, moreover, has its own special coefficient of solubility. While nitrogen is feebly soluble, ammonia is highly so. This fact helps us to understand why it is that the gases which spontaneously dissolve in water in contact with the atmosphere do not, when extracted from the water, yield a mixture even distantly comparable to air: how it is that the elements of air are not found in water under the proportions they bear to each other in the atmosphere. While water contains the constituents of air, it contains such proportions of these constituents as are peculiar to it. However, the latter are provided in sufficient quantity, and normal river water is quite adequate to maintain the life of aquatic animals. This applies to fresh waters generally, for ponds and lakes have the same conditions as rivers.

Some special points are to be noted concerning salt water. Of course the constituents of atmospheric air are met with in sea water. But, generally speaking, the variations in the proportions of these constituents are less numerous and of less importance. The seas, generally considered, make up a more homogeneous whole than any river of large dimensions. Between the south Atlantic and the north Atlantic less differences are to be expected, and less found, than in the Thames or the Seine, below and above London or Paris. A priori it is obvious that there are less causes of difference in aeration in the two parts of the Atlantic than there are in any of the two rivers in two points not 10 miles apart. It is quite obvious also that local differences, such as exist at the mouth of a great river that has just passed through a large town, as is the case with the Hudson, the Thames, or the Gironde, must be very soon dissipated in the enormous mass of the ocean through the agency of tides, currents, and winds. Upon the whole, generally speaking, none of those local differences are of any real importance. There are, however, differences which should be noticed, but their causes are quite different from those which obtain in the preceding case. The most important are observed when we compare specimens of water obtained from different depths. Carpenter noticed the fact and comparing specimens of water obtained in the same vertical line, at depths of 750, 800, and 862 fathoms, he observed the following composition of the air extracted:

	750 fathoms.	800 fathoms.	862 fathoms.
Oxygen	18.8	17.8	17.2
Nitrogen	49.3	48.5	34.5
Carbonic acid	31.9	33.7	48.3

While the proportion of oxygen decreases with increasing depth, that of carbonic acid increases in a marked manner. No very satifactory explanation of this fact has been yet provided.

We have now sufficiently dwelt upon this topic, and none will doubt that air—that is, the constituents of air, to put it in exact terms—intimately mingles with the waters that cover three-fourths of our planet. While waters do not contain atmospheric air as such, and while the gases dissolved in them do not make up normal air, they contain the elements of the latter, and the proportions are sufficient to maintain aquatic life. We may consider that these elements are found in water, even at the most considerable depths, although we have no positive proof of it.

Now, it is quite clear that since the mass of the waters contains organisms that breathe and live, and since life goes on notwithstanding the unceasing production of carbonic acid and the destruction of oxygen, both necessary consequences of their life and respiration, there

must exist some unceasing agency by means of which new oxygen is added and carbonic acid carried away. Otherwise aquatic life would soon cease. In other terms, there must exist a perpetual exchange between the gases dissolved in the waters and those which make up the atmosphere, just as there goes on a perpetual exchange between the air of any place where the atmosphere is vitiated—a town, a manufactory, a room—and the air of the streets or surrounding country. And the exchanges which go on between air and water, and between the general atmosphere and those multitudinous centers, great or small, where the normal proportions of the gases of air are being constantly altered, must indeed be most nicely adjusted, since by no method have we yet been able to detect any alteration in the composition of the atmosphere. The equilibrium must be unceasingly maintained. That equilibrium is a very interesting matter. Interesting in two senses—practically, since life depends upon it, and from the scientific point of view, as it is the consequence of a general established law.

How, then, is that exchange effected between air and water, without which life would soon extinguish all life, without which the living organisms of water would soon render life impossible to themselves and to their congeners? By means of what may be termed "the breathing of the waters." The waters breathe—that is, expire obnoxious gases and inspire those that are useful: they expel carbonic acid and collect oxygen. Diffusion is the main agency of this grand function of waters, and it is enough that both air and water be in presence and contact to insure the operation. But diffusion is not alone at work; another agency cooperates. It does not at first seem that dust would have any influence, and few would suppose that it plays any part here. It does, however, and the enormous quantity of it which, imperceptibly in most cases, is carried from the land over the seas, where it falls and slowly sinks to settle at the bottom as a soft red or gray mud—the first stage of new strata of rocks—is a great help toward the respiration of the seas. As J. Thoulet has shown, every particle, however small and minute, carries some air which adheres to it and does not escape when submerged: this air slowly dissolves in the surrounding water. The experimental proof is easy. Bring some water to the boiling point, in order to expel the gases dissolved in it, and then add some potash and pyrogallic acid. This mixture turns black when in presence of oxygen by reason of the action of the latter on the acid. Under ordinary conditions, the experiment being thus prepared, what one witnesses is this: The surface of the water blackens and the black color extends slowly toward the bottom, according to the ratio of diffusion of atmospheric oxygen in the mixture. The rapidity, or rather slowness, of the change of color is the measure of the slowness of diffusion. Now, throw some fine dust into the vessel containing the water so prepared. What happens then is that each grain or particle, while falling through the liquid, leaves behind it a black line which marks its path exactly, and

there are as many vertical streaks in the colorless solution as there were particles of dust thrown into it. Each particle's atmosphere of air acts upon the pyrogallic acid, and instantly causes the change of color. The experiment is a very elegant one, and provides a very convincing demonstration, and when one thinks of the number of dust particles (either of terrestrial origin or coming from the interplanetary spaces under the form of microscopical meteorites) which uninterruptedly pour down on the oceans like some paradoxical dry rain, it is conceivable that the importance of these infinitesimal particles to all aquatic organisms is great. From this point of view, a catastrophe like that of Krakatoa becomes a blessing, and each volcanic outbreak with its concomitant cloud of dust and cinders, which often spreads over hundreds of square miles, and gives forth a soft slow rain of solid particles which fall through the air to the water and thence to the underlying abysses, is doubtless a benefit to aquatic organisms. It may seem absurd to speak of the beneficial influence of volcanic catastrophes upon the denizens of the ocean; the fact is nevertheless incontestable. Nature abounds in such curious and unexpected interactions. Most of these, as yet, escape us, but some now and then become apparent, and go to show how difficult and complex is the study of life or biology, in its real sense, and how essential is the knowledge of circumstances and surroundings.

The experiment which has just been referred to suggested to Paul Regnard the means of measuring, so to speak, the rapidity of the ocean's respiration, the rapidity of diffusion of the aerial gases in water, and especially that of oxygen, which is the most important for organisms. The method is very simple. All that is required is a large glass tube, some 3 yards long, closed at the lower end, placed vertically, and filled with water holding Coupier blue in solution, saturated with hydrosulphide of soda. This solution, a pale yellow in color, turns blue under the influence of oxygen. The tube thus filled is left to itself and each day an observation is made of the point to which the blue layer has extended. The first day the mere surface only is blue, but by degrees the underlying strata also turn blue, according to the rapidity with which atmospheric oxygen diffuses and is absorbed. Under such circumstances, P. Regnard noted that in the course of three months oxygen diffused no farther than about a yard from the surface, and the rate of propagation is hardly a centimeter per day. If such is the normal ratio, air penetrates water at the rate of 4 meters per year, and if, "at the beginning"—of which so much is said, and so little known or knowable—the sea was entirely devoid of oxygen, no less than a thousand years were required to allow atmospheric oxygen to penetrate to the depth of 4,000 meters, a depth which we all know is not uncommon in the ocean.

It is thus seen that the respiration of waters is very slow—at least it is very slow so far as diffusion alone is concerned. But, as already

noticed, diffusion is not the sole agency, and it is quite clear that the white crested waves, all foam and sparkling with air bubbles, that the winds, the currents, the tides, and lastly the dust particles have done and are doing much to hasten the process, and accelerate the execution of the great respiratory function of the deep. No method, unfortunately, has yet been devised for measuring the rapidity of this process; and before it can be done, some manner by which the approximate number of dust particles falling into the seas can be ascertained should of course be discovered. The problem is a difficult one, truly.

II.—Air from the Chemical Point of View.

Considered by the ancients, and even by modern philosophers till a very recent period, as one of the four initial elements (earth, air, water, and fire), air was unable to keep this position after the birth of modern chemistry. Like most other substances it has had to reduce considerably its pretensions. They were of no avail in presence of the methods of chemistry. Instead of being, as formerly supposed, an element, a homogeneous matter out of which no known method of reduction can obtain two or more differing substances, air has shown itself to be nothing more than a mixture of different elements. A mixture, a mechanical mixture; not a compound. Air is not like water, in which two gases, oxygen and hydrogen, are combined and make up a third body exceedingly different in properties from those out of which it is made, nor like the enormous number of compounds known to chemistry in which two or more elementary substances are combined in definite proportions and form new substances more or less peculiar, but invariable, and possessing properties which neither of the elements possesses; it is a mixture only. This may be demonstrated in various ways. When nitrogen and oxygen, the fundamental elements of the air, are mixed together, no heat is evolved, no heat is absorbed, as is the case in the preparation of most compounds. Again, the refringency of air is equal to the mean of the refringency of oxygen and nitrogen when experimentally mixed in the proportions in which they occur in the atmosphere; and the ratio of oxygen to nitrogen is not a simple one; lastly, when in presence of air, water dissolves different proportions of the different constituents of the former; it dissolves each gas according to its own proper coefficient of solubility.

These four proofs are considered as more than sufficient to show that air is a mixture, not a compound. It may be added, moreover, that while the composition of the atmosphere is fairly uniform as a whole, it is not absolutely so; the one or the other constituent is more or less abundant according to circumstances. No chemical compound offers such variability in composition; its constituents are constant, always the same, and in the same ratios, while in a mixture every variation is possible, and may be expected.

And now, what are the constituents of this mixture? Our knowledge of these elements, as well as that of air itself, considered as a whole, is of recent date. While it would require more space than we can spare to give a full historical account of the chemistry of air, the principal facts may be briefly summarized.

As has been previously stated, a French physician, Jean Rey, was the first who proved the materiality of air, and his experiment was repeated and confirmed by Galileo in 1640, and by Otto von Guericke in 1650. Jean Mayow, in 1669, was the first to prove that air is not an element, a homogeneous substance. He suspected the fact that air contains two different gases, of which the one, which he called "nitro-aerial," maintains combustion or fire and respiration, while the other does nothing of the sort. In short, he suspected the presence of the two different gases which are now named oxygen and nitrogen. Had he lived longer, Mayow might have discovered the facts which are the basis of Lavoisier's fame.

In 1774 Priestly[1] made a great step in the right direction when he succeeded in obtaining the separation of the two principal gases which make up air, and on the same date Scheele[2] did the same, going somewhat further, as he discovered the ratio of what he called "dephlogisticated air" (or oxygen) to "phlogisticated air" (or nitrogen). Both, however, fell into the same error. Both considered the two gases as identical, but possessing different properties. No doubt the properties are different, but the differences are inherent to the gases themselves; the one is not a form of the other and can not be transformed into the other, and the differences are much more numerous than these two pioneers of chemistry perceived.

To Lavoisier was reserved the honor of providing precise and unassailable knowledge concerning the nature and composition of air. To prove that air, as already demonstrated, is made up of two elements, the one adequate the other inadequate to maintain combustion and respiration, was no difficult task. But he went farther on his road by means of the following experiment, one that is fundamental in the history of chemistry: He placed a known amount of mercury, carefully weighed, in a retort whose long curved neck opened into an inverted glass tube placed on a mercury trough. By means of a curved pipette he sucked out part of the air in the tube, and consequently the mercury rose within it to some height. The point to which the mercury rose was carefully marked, and then the retort was submitted to the influence of heat. The temperature was 360° C., and on the second day he perceived that small red pellicles were forming at the surface of the mercury. During a week, the heating being continued, the pellicles kept forming, and then no more appeared. He kept up his fire during four days more and then put it out. When the apparatus was cooled

[1] Born in England in 1733; died in Pennsylvania, 1804.
[2] Born in Sweden in 1742; died 1786.

down, he saw that in the glass tube the mercury rose higher than before the experiment, and he observed that the remaining gas was unable to maintain respiration and combustion. In it small animals died and a light went out. He then collected the red pellicles, weighed them, put them in a retort whose neck opened under a glass tube filled with mercury, and heated the retort to 400° C. The pellicles melted away: they yielded a certain amount of mercury which was deposited in the neck of the retort, while in the glass tube some cubic inches of a peculiar gas had accumulated at the top. The volume of this gas corresponded exactly with the volume of air which had disappeared in the preceding experiment, and this gas was fully able to maintain combustion.

Thus was performed the first analysis of air, and Lavoisier came to the conclusion that that fluid contains two gases—one which forms one sixth of the whole volume and is favorable to combustion and respiration, while the other, amounting to five-sixths of the whole volume, is favorable to neither. The first was oxygen; the last azote, or nitrogen.[1]

It is now more than a century since these facts were discovered, and became the corner stones of modern chemistry. Up to that time it was mere empirical alchemy, and a fabric of erroneous notions. A number of methods, much superior as far as precision is concerned, have been devised for the purpose of air analysis, and of gas analysis generally.

The eudiometric method, propounded by Gay-Lussac and Humboldt, is one of the best known. It is based upon the fact that if hydrogen is added to air, and the electric spark passed through the mixture, the oxygen of the air and the hydrogen added to the mixture combine in definite and constant ratio and form water. A very simple calculation gives the amount of oxygen contained in the mixture. The weighing method of J. B. Dumas and Boussingault, invented in 1841, is quite different. It is based upon the fact that when air, deprived of aqueous vapor and carbon dioxide, is made to pass through a tube containing metallic copper reduced by means of hydrogen, and heated to redness, it yields its oxygen to the copper, and if the copper is weighed before and after, the amount or weight of oxygen contained in the volume of air experimented upon is at once known. If the remainder of the gas, that portion which has not combined with the copper, be collected in an empty receiver weighed before and after the experiment, the increase in weight of the receiver shows the quantity of nitrogen contained in the original volume of air. Twenty other methods, more or less similar to the preceding one, have been devised by Brunner, Regnault and Reiset, Doyère, Bunsen, Williamson, Russell,

[1] These names were given by Lavoisier. Oxygen is derived from ὀξύς, acid, and γεννάω, to produce, because one of the properties of oxygen is to form acids when combined with many other substances. Azote is derived from privative α and ζωή, life, because azote is not suitable for living animals, and can not maintain life.

etc., but this is not the place to describe them, and all text-books of chemistry give a full account of them.

It is enough for our purpose to know that it is fully established that atmospheric air is a mixture; that this mixture is principally made up of oxygen and nitrogen, and that we are provided with methods and implements by means of which air may be analyzed, and the least traces of its constituent elements detected.[1]

These elements are numerous, but they differ greatly in importance.

Fundamentally, air comprises 20.81 volumes of oxygen, 79.19 volumes of nitrogen, and some ten-thousandths of carbon dioxide. In some localities or under certain circumstances a few other[2] gases may also be found in air, in very small quantities.

We must now consider in turn each of these elements.

Oxygen comes first. Not that it is present in the greatest abundance, but from many points of view it is a most important part of the atmosphere.

This gas is heavier than air as a whole (while nitrogen is lighter), and in 1,000 liters of air there are 208 liters of oxygen against 792 of nitrogen. This ratio seems to be constant, although Dalton and Babinet, arguing theoretically, supposed that oxygen is less abundant in the air at high altitudes, and that the proportion of this gas decreases as the distance from the sea level is increased—oxygen being rather more abundant in low regions, and near the surface. Of course, if such were the case, the reverse would obtain for nitrogen. This gas should be more abundant at high levels, and less near the sea level. According to the views of Dalton and Babinet, at 10,000 meters above the sea level, 1,000 liters of air should contain only 184 liters of oxygen against 816 of nitrogen. These speculations may be interesting, but as they

[1] In view of recent facts this is too positive a sentence. Great was the surprise of the chemists when they heard that Lord Rayleigh and Professor Ramsay had discovered a new element in atmospheric air. This should inspire them with some caution, and induce them not to put so much faith in the infallibility of their methods. More of this hereafter. [Note added to proofs in 1896].

[2] To the normal constituents of atmosphere one remains to be added, and that is argon, discovered in the year 1894 by Lord Rayleigh and Professor Ramsay, to whom, on this account, the $10,000 Thomas Hodgkins prize has been most deservedly awarded.

Argon, thus called because it seemed to be an inert and inactive gas, slow to combine with other substances, was certainly contained in Cavendish's test tubes, but Cavendish considered it as nitrogen, and thus failed to add this substance to the list of chemical elements. Argon is present in the atmosphere in the proportion of somewhat less than 1 per cent; M. Th. Schloesing obtains 0.935 argon for 100 air, in volumes. MM. MacDonald and Kellar have in vain endeavored to detect argon in the chemical constitution of animals and plants (mice and pease), but Mr. Ramsay has found it in meteoric iron. Argon liquefies at —128° under 38 atmospheres pressure, and freezes at —189°. It is not as inactive as at first supposed, as Berthelot has been able to combine it with benzine under the influence of the electric discharge. This gas does not seem to play any active part in respiration; it is inert and useless, like nitrogen. [Note added to proofs, 1896.]

are in direct contradiction with positive facts and observations we may dismiss them as "children of fancy." The chemist Thénard analyzed air collected at 7,000 meters height by Gay-Lussac, and found no trace of such difference. Similar observations, due to Dumas and Boussingault, prove that these theories are not sustained by stern reality, and, in brief, chemists are agreed that, as far as oxygen and nitrogen are concerned, the composition of atmospheric air is uniform and constant, with very slight exceptions. This is the result of numerous observations made in different and distant places, at different heights, at distant epochs, and Dumas and Boussingault, who have devoted much work and time to the matter, have always obtained similar ratios, or at least ratios so nearly identical that the differences are not more considerable than may occur in the best-conducted experiments—they keep within the limits of unavoidable errors. So we may consider air as being as perfectly uniform in composition, as it might be expected to be in view of the circumstances.

Now, where did this oxygen originate? Whence does it come? From what source is it supplied? A complete answer to this question can only be given by those who know how things stood in the beginning, and who understand the origin of matter, force, life, and some other of those troublesome and perplexing problems. Oxygen must be a very anciently established inhabitant of our planet, and its origin, like that of the "old" families, is lost in obscure mystery. At all events there it is, and wherever it comes from, howsoever it has been evolved, one thing seems positive, and that is the fact that there are at present, as far as we know, no important sources whence a considerable amount of this gas may be derived and added to the current stock. In view of this, the stability of its normal ratio in the air, notwithstanding the enormous quantity of it consumed by living beings and in combustion, becomes a riddle well worthy of some attention.

We know that the entire atmosphere contains over one million billions of kilograms of oxygen; that nearly one-half of the weight of the minerals of our globe is oxygen; that eight-ninths of the weight of water consists of this same gas, which is, moreover, abundantly present in the tissues of all living organisms. On the other hand, we know at present of but one source of oxygen, discovered by Priestley, and further investigated by Perceval and Senebier. I refer to plants. It is a fact familiar to all that plants are endowed with the faculty—ascribed to the chlorophyll contained in their tissues[1]—of breaking up carbon dioxide into its elements; that is to say, into carbon which goes to the repair or increase of the tissues, and oxygen, which, on being freed, diffuses itself throughout the surrounding atmosphere. There certainly is one source of oxygen. Are there any others? Their existence is doubtful. Of course we know that a number of chemical

[1] The fact is probable but not certain, for chlorophyll has not yet been satisfactorily separated from the tissues in order to investigate its chemical powers.

reactions effect the liberation of oxygen, water electrolysis, the decomposition of chlorate of potassium, or of sulphuric acid under the influence of heat, for instance; but do any of these chemical processes, or any others similar in result if not in method, occur in nature on any important scale? We do not know, but it seems doubtful. At all events, since the composition of the atmosphere remains fairly constant, there must be some agency by means of which the enormous mass of oxygen which is daily, hourly, at every moment, absorbed in consequence of the organic and inorganic combustions occurring over the whole globe, is, sooner or later, returned to the atmosphere. Plants are the only agency at present known by which this process is effected. At all events they effect part of it. But are they equal to the task of effecting the whole? The question has not been yet answered in quite satisfactory terms. Mr. T. L. Phipson has recently endeavored to fill this gap, and to show that plants are even a more important source of oxygen than is commonly admitted. He cultivated a convolvulus plant in an artificial atmosphere. entirely devoid of oxygen, but containing some proportion of carbon dioxide. with the result that a part of the latter gas disappeared, its place being taken by oxygen, which can only have been evolved by the plant. Mr. G. Meyer had previously expressed the opinion that oxygen is thus generated, but Mr. Phipson's experiment is of great interest. The whole matter is very important, for, if the oxygen contained in the atmosphere has been evolved by plants, one may ask whether there has not been some time when the atmosphere was very poor in oxygen and very rich in carbon dioxide, and whether some time may not arrive when, conversely, the atmosphere will be well provided with oxygen and very deficient in carbon dioxide. If such were to be the case, the equilibrium and homogeneity of air, as far as its composition is concerned, would be very unstable and temporary matters. But no answer of a satisfactory character can yet be given to such questions.

It may be added that, according to less recent data, 1 hectare (a little over 2 acres) of forest exhausts each year the atmosphere of some 11,000 kilograms, or 5,596 cubic meters, of carbon dioxide, while in return it yields nearly as much (5,594 cubic meters) oxygen. A field of oats, similarly, returns about as much oxygen as it absorbs carbon dioxide. Perhaps other agencies are at work and make up for the enormous consumption of oxygen effected by human, animal. and plant respiration, and by inorganic combustions generally, and it does not seem to us that adequate proof has yet been furnished that plants alone are able to return to the atmosphere the oxygen which they, with all other living beings, take from it. Leaving out of the question the subject of the origin of oxygen, it is very difficult to ascertain the methods by which, notwithstanding an enormous consumption, the ratio of this gas remains fairly constant at the present time.

While the proportion of oxygen in air is constant, or tolerably

uniform, it must not be forgotten that certain local conditions may tend to increase or decrease its normal ratio. Nor could it be otherwise. However rapid the diffusion of gases, it is reasonable to suppose that when one of the constituents of the atmosphere is being rapidly subtracted or added in great quantities, the normal ratio in that vicinity must be more or less altered. In a crowded room where ventilation is inadequate the ratio of oxygen decreases, and the same happens in places where intense combustion is going on—in mine shafts, where slow oxidization of materials is a nearly constant phenomenon. In brief, where the destruction of oxygen is not compensated by rapid ventilation, the proportion of this gas to the remainder of the air must decrease. Under the same conditions, of course, the ratio of carbon dioxide must and does increase, as repeated observations have shown. But such local accidents, such limited alterations of the composition of the air, have no influence on the general atmosphere; they are temporary, very slight, and therefore rapidly obliterated. Even the respiration of some two, three, or four million inhabitants, as in a large city, does not affect the composition of the air of the streets; and London, Chicago, or Paris exert no more influence on the surrounding atmosphere, into which they pour torrents of carbon dioxide, than any forest, for instance, where the case is reversed, and where oxygen is produced in abundance. Diffusion takes place immediately, and no appreciable alteration can be detected, save in very limited spaces and for a short period. And while the one gas is being removed in one place it is being added in another, and thus a compensation is rapidly effected.

Little need be said concerning nitrogen. This gas, as already stated, was discovered by Priestley, and Lavoisier showed that it is one of the elements of air. Its weight is lighter than that of air as a whole, and in 100 liters of air there are 79 of nitrogen. It neither burns nor maintains combustion; it plays no part in respiration; it can not help to maintain life. Not that it has any toxic properties, assuredly; but it is inert, indifferent, inactive. Little is known concerning its origin. We know that some mineral springs, sulphurous springs particularly, yield a certain amount of nitrogen, and the air ejected from the lungs of animals contains about as much as the same air when inspired. As is the case with oxygen, nitrogen seems to occur in the atmosphere in the same ratio everywhere.

The two gases, oxygen and nitrogen, are the main constituents of air, and compose the greater part thereof. They are the essentials, the other components, which must now be noticed, occurring only in very limited quantities, some in variable and small proportions. We might almost say that they are accessory components, judging from their quantity, had not experience shown that one of them at least plays a very important part in biology, one no less essential, in fact, than that of oxygen, for instance. This latter component is carbonic acid or carbon dioxide. It occurs only in very small quantity, 4 or 5 liters in 10,000

liters of air. This gas is comparatively heavy, and Priestley was cognizant of the fact that it is unable to support combustion or respiration. The proportions in air are not uniform and constant; they vary according to circumstances and places much more than is the case with the other gases. As early as 1827 De Saussure discovered very marked differences, obtaining as extreme figures 3.15 and 5.74 per 10,000. More recently, Boussingault and Lévy, comparing the proportion of carbonic acid in the air of Paris with that in the air of Andilly (a small village some 12 miles from Paris, near Montmorency), found also a notable difference between the two, there being 3.19 (per 10,000) in Paris and 2.99 in Andilly. Again, a somewhat smaller difference has been noticed by Roscoe and McDougall between the air in Manchester and that of the surrounding country; but at Clermont-Ferrand, in central France, Truchot found 3.15 per 10,000 and but 2.03 at the top of the Puy-de-Dôme, a neighboring mountain, and 1.72 at Pic de Sancy, another peak of the same group.

These instances are enough, we presume, to show that the ratio of carbonic acid to the total volume of the air varies considerably, much more than that of the two previously mentioned gases, and that this component is more abundant in cities than in the country.[1] This should not occasion wonder, as the amount of carbonic acid varies according to various circumstances of time and place. For instance, De Saussure noted that it increased during the night and during cloudy weather; its ratio changes with the season, from one year, and even from one month, to another, irregularly, and, in fact, from day to day. Above the ocean the variations are less, and in mid ocean the air is purer than over the continents. The same obtains on high mountains.

If, instead of considering the composition of air collected in the streets, in the country, or on mountains, we compare rather that which we breathe in dwellings and in all confined spaces where ventilation is more or less deficient, and where organic and inorganic combustions take place, with that which obtains in the open, the differences are still greater. Of course, it should be so. We must not forget that the air which each one of us expels through mouth or nose, at this very moment, contains nearly a hundred times more carbonic acid than was contained in the same air when we inhaled it a few seconds ago. This being the case, it is sufficient to imagine a confined room where one or many persons are sitting; there most certainly, provided the experiment lasts long enough, we shall find many different and increasing proportions of carbonic acid. That is, we might were the experiment not self-limited. For though, as Pettenkofer has observed, the 0.40 or 0.50

[1] In Austria, the amount of carbonic acid is about 34.3 liters per 100 cubic meters of air; in Germany it varies between 32 and 34; in the desert of Lybia, Von Pettenkofer found from 44 to 49. These are rather high figures. During the expedition for the observation of the transit of Venus, analyses made in different countries gave the following results: Florida, 29.2; Mexico, 27.3; Martinique, 28; Haiti, 27.8; Santa Cruz, 26.6. At Cape Horn, Hyades observed 23.1 and 28.5 as extreme figures.

per 1,000, which is the normal proportion of carbonic acid, may rise in a tolerably well-ventilated room to 0.54 and 0.70, or to 2.4 in an ill-ventilated sick room, and reach to 3.2 in a lecture room, 7.2 in a school-room, and even 21 in a stable in the Alps where men and beasts are huddled together in winter, the chinks being stopped against the cold, there occurs a limit which can not be passed; if the ratio increases, men and animals must soon die, and the experiment is over, the production of carbonic acid having come to an end. When the composition of the surrounding atmosphere is the same as that of the air which each of us expires (over 4 per cent carbonic acid, and less than 16 per cent oxygen), death must soon result, because there is too much carbonic acid in the air to allow that in the system to escape, and not enough oxygen for the needs of the body. More will be said on this point later on. It is enough here to show how considerable the ratio of carbonic acid may become in confined space, and how much greater are the variations in carbonic acid than in oxygen or nitrogen.

The cause of these variations is obvious. They are in close relation to the variations in the production of the gas under consideration, and upon this matter information is abundant.

Carbonic acid is produced in many ways; it has many sources. One of them has been referred to—animals and mankind. Bipeds and quadrupeds, in fact all animals, indeed, all living organisms, are sources of carbonic acid. All beings, from mere yeast cells to the lords of creation, breathe; all or nearly all take oxygen from the air and return carbonic acid to it. It is a familiar fact that fermentation in most cases—in the case of sweet substances particularly—is accompanied by a considerable production of carbonic acid. In wine-producing countries cases of asphyxia often occur in the cellars where fermentation is going on, owing to the amount of carbonic acid produced. All higher organisms, plants, and animals have the respiratory function, and one of the acts of respiration is the elimination of carbonic acid through the lungs. This unceasing production of carbonic acid by living organisms, whether plants or animals, is very variable in its activity, even within the limits of the same species and of the same individual. It is well known that the male produces more than the female, the adult more than the very young or the very old individual, the strong more than the weak, etc. It is well known, also, that this production of carbonic acid is increased by exercise, movement, light, and food, while it is decreased by rest, darkness, inanition. On the average each man exhales 20 liters of this gas per hour, and nearly 1 kilogram per diem (of twenty-four hours). The production is more considerable in sheep, and a bull exhales between 7 and 8 kilograms during the same lapse of time. However, in order to well appreciate the ratio of carbon dioxide exhalation, instead of considering the whole amount produced by any individual, it is better to refer this amount to the weight of the individual animal or person, to ascertain the quantity evolved per kilogram of weight. Viewing the

matter in this light, we perceive that birds are the animals that give out the greatest quantity of carbonic acid. While 1 kilogram of ox excretes from 3 to 7 grams of carbon per twenty-four hours, 1 kilogram of fowl or turkey excretes 20 grams on an average, 1 kilogram of young chickens 56 grams, and 1 kilogram of sparrow nearly 60 grams. These facts quite agree with the exceedingly active respiratory function of birds, especially small birds.

Boussingault many years ago established the fact that the town of Paris alone, taking into consideration men and horses only, exhales nearly half a million cubic meters of carbonic acid per twenty-four hours (at present three-quarters of a million would be nearer the mark, but still even below it), and estimating the whole population of the globe as being one billion and a half, we find that mankind alone pours into the atmosphere one billion and a half kilograms of carbonic acid per diem (1,500,000,000 kilograms); that is to say, 720,000,000 cubic meters. Per annum the grand total is, in round numbers, 547,500,000,000 kilograms, or 262,800,000,000 cubic meters. So much for mankind only. If we wish to take into account the production of carbonic acid by animals, the difficulties are certainly great, and we can only proceed inferentially, and with less certainty. Girardin puts the production of carbonic acid by animals at something like double that of mankind, if not treble—let us say double, which means 1,095,000,000,000 kilograms per annum. But there remain other sources of carbonic acid: all plants which, although decomposing carbon dioxide as part of their method of nutrition, breathe in the same manner as animals, and exhale carbonic acid; all the combustions going on in our houses—fires, lights—in our factories and works, etc. (in Europe alone 550,000,000 tons of coal are burned each year, which means 80,000,000,000 cubic meters of carbon dioxide); the slow but uninterrupted production of the gas which is going on over the whole globe through the gradual combustion of decaying vegetable matter; the mineral springs—those of Auvergne only in France, giving off, according to Lecoq, some 7,000,000,000 cubic meters of gas; volcanoes and their surroundings—Cotopaxi alone being considered by Boussingault as giving off more carbonic acid than a whole city like Paris; the natural sources of gas, such as the Grotta del Cane[1] near Naples, etc. Under such circumstances, it is very difficult to form any idea of the total amount of carbonic acid discharged into the atmosphere. Armand Gautier, however, comes to the very probable conclusion that this amount can not be very far from 2,500,000,000,000

[1] The air in this grotto contains more than half its volume in carbonic acid. It derives its name from the fact that, in order to illustrate the noxious effects of the inferior stratum of air (where carbon dioxide, heavier, accumulates), it is the custom to introduce a dog into it, which soon falls, affected by asphyxia, while the visitors, owing to their higher stature, breathe the normal air, and feel nothing unusual. The dog, it must be added, is at once taken out into pure air, and soon revives, going through the experiment several times a day. Its health is very good, but its temper becomes unpleasant when a visitor appears. The animal knows what is coming.

cubic meters per annum, which means over 5,000,000,000,000 kilograms, the weight of the total atmosphere being 5,000,000,000,000,000,000—that is, one hundred thousand times greater. At all events, this is certainly below the mark.

Such being the enormous rate of production of carbonic acid, one may well wonder that the ratio of this gas in the total atmosphere remains as small as it is, it being easy enough to reckon what the ratio would become in the course of ten, twenty, or a hundred years, if there were not some agency at work by means of which it is destroyed or combined, and without which life would soon become extinct. That such agencies do exist and are in operation is a positive fact, and though we may not be acquainted with all of them, there are three at least which deserve notice. These agencies are plants, animals, and oceans.

Plants occupy the first place: for, while producing carbonic acid which they breathe, they absorb it in the course of the process of nutrition, taking its carbon into their tissues and yielding its oxygen to the atmosphere.[1]

Animals should be considered next: not all, to be sure, but all those which have a calcareous skeleton, internal or external. Such are corals, such are shellfish generally, and all aquatic and terrestrial animals, which, having a calcareous skeleton, must necessarily contain some amount of carbonic acid combined with lime. This compound seems to hold good for a long time, and if there are cases where the skeleton after death slowly decomposes, so that the carbonic acid has some chances of getting free again, there are a great many more in which it is preserved, and we know of considerable geological strata which are nothing else than enormous accumulations of the remains of animals that died centuries and hundreds of centuries ago. This process, by means of which a considerable amount of carbonic acid becomes fixed and imprisoned, so to say, was exceedingly active in earlier times; it is also very active at the present period, and the great space taken up by coral reefs in the mid Pacific and other oceans is but a gigantic laboratory of nature where carbonic acid is being, if not destroyed, at least hoarded and put by under a compact form, and, for a time at least, withdrawn from the general circulation of matter. To appreciate the importance of the storing process, it is only necessary to measure the thickness

[1] A writer in the Belgique Horticole, Vol. XXXV, 1885, p. 227, gives the following evaluation: One hectare of forest (1 hectare equals 2.471 acres) produces yearly 3,000 kilograms of carbon—1,600 kilograms under the form of wood and 1,400 under the form of leaves (weighed dry and exclusive of other substances). During one hundred and fifty days (on the average) of active vegetation, the trees must draw from the atmosphere 5,596 cubic meters (11,000 kilograms) of carbon dioxide. In exchange they give nearly as much oxygen (5,594 cubic meters). With a field of oats the same proportion obtains—as much oxygen is given off as carbonic acid is taken in. Thirty-two persons give off as much carbonic acid as is taken in by 1 hectare of oats or of forest, and they burn as much oxygen as the said surface of field or forest produces.

and extent of such masses of organic remains. All know that in every geological formation calcareous strata of great thickness are found, which are merely agglomerations of skeletons, and Van Dechen has endeavored to form some idea of the quantity of carbonic acid which may be contained in such strata. The result is very striking. He comes to the conclusion that in the lime strata of the Carboniferous epoch alone there is an amount of carbonic acid imprisoned which is six times more considerable than that at present contained in the whole atmosphere. The problem has been carried further by Sterry Hunt. Taking this result into consideration, and forming an estimate of the whole quantity of carbonic acid combined with lime in the whole geological series, he finds that the amount of carbonic acid thus imprisoned in the calcareous rocks would, if entirely liberated, form an atmosphere two hundred times more considerable than that which at present surrounds the planet. In such a case the pressure would be so much increased that the gas would necessarily become liquid. The inference which he draws (Brit. Association for the Adv. of Science, 1878) is that the enormous amount of carbonic acid at present stored in the depths of geological strata has never been simultaneously, even for a short time, present in the atmosphere, but that it must have reached the latter in small quantities and gradually. Mr. Sterry Hunt is of opinion that all this carbonic acid has come to our planet from celestial regions in the course of hundreds of centuries. Whatever may be thought of this interpretation as to the origin of the gas, one fact remains unassailable, and that is the enormous quantity of the latter stored up in the earth's crust; and if in the course of time organisms have been able to accumulate such a provision and are still operating as they undoubtedly are under our very eyes, we certainly can not help coming to the conclusion that we have here one of the most important agencies by means of which the atmosphere is being unceasingly kept sufficiently pure for maintaining life.

Lastly, come the oceans. Few are aware that the salt waters play a most interesting and important part in the general regulation of the atmosphere, and are one of the agencies which by absorbing carbonic acid prevent it from overaccumulating in the air. Mr. Schloesing's remarkable investigations have shown that the seas contain a large amount of dissolved carbonic acid, a much larger amount, in fact, than is to be found in the whole atmosphere. The equilibrium is preserved as follows: When carbon dioxide becomes more abundant than usual in air, in consequence of an increased production of this gas, and no compensatory destruction or withdrawal is effected by plants or animals, part of it dissolves in the salt waters, and combines with the insoluble and neutral carbonate of lime, always present there, producing a soluble bicarbonate of lime which dissolves immediately, and, inversely, if the amount of carbonic acid in the atmosphere decreases, the soluble bicarbonate is decomposed into carbonic acid, which is set free and diffuses

throughout the atmosphere, and neutral carbonate, which remains in the water. Briefly, so long as the tension of carbonic acid in the waters and that of carbonic acid in the atmosphere is the same, nothing is produced, but as soon as this equilibrium of tension is destroyed the sea restores it by the very simple process just described. This chemical adjustment works automatically at the moment it is needed, and to the extent and in the direction required. It must be added that this equilibrating function is possible mainly through the circumstance that the ocean contains a much larger amount of carbon dioxide than the atmosphere; according to Mr. Schloesing, about ten times as much. However great, then, the production of carbonic acid may be on the surface of the globe by all the agents we have enumerated, it would seem that the proportions of this gas in the atmosphere as a whole can vary but slightly, owing to the power of the sea to absorb it and maintain the equilibrium.

We have now exhausted the list of the agencies through which the amount of carbon dioxide in the air may be and is reduced when necessary, and they are important and powerful enough, as we have seen, to be equal to probable emergencies. Without them the globe would soon become uninhabitable. Poggendorf, in fact, has found that if all carbon dioxide produced could accumulate in the air the proportion would be doubled in eighty-six years. A few centuries would see the last of life as far as superior organisms are concerned.

Oxygen, nitrogen, carbonic acid, such are the main constituents of air. Those which follow are of less importance, but deserve a passing notice.

We may begin with ozone. This gas, discovered in 1840 by Schoenbein, has been made the subject-matter of many investigations by De Marignac, De la Rive, Becquerel, Frémy, Andrews, Tait, etc. Ozone is oxygen under a peculiar form—condensed oxygen, so to say, oxygen of high potency. It possesses strong oxidizing properties, and the amount which is found in the atmosphere varies considerably according to circumstances and places. This amount is on the average of 1 milligram per 100 cubic meters of air; $3\frac{1}{2}$ milligrams are a maximum. This gas is generally wholly absent from the atmosphere of cities, and in the air which has passed through large centers of population. Paris offers good opportunities for illustrating this fact. When the wind is northerly, no ozone is found in the air at the Montsouris Observatory, situated in the south of Paris, while, when the wind is southerly and comes over the country without having yet crossed the town, ozone is found in the air. Generally speaking, then, the healthiest part of all towns is that which lies in the direction from which the prevailing wind comes; the air is purer and fresher and contains more ozone. In western Europe, where the prevailing winds are westerly and northerly, the northwestern and western parts are the most eligible.

The cause of the difference in the amount of atmospheric ozone is

to be sought in the fact that cities contain a much larger quantity of oxidizable organic material than is the case with the country and small villages, and the result is that more ozone is absorbed from the atmosphere over and around cities than from the atmosphere over the country, over the fields, and especially over the oceans. Generally speaking, ozone is more abundant near forests and the sea; the atmosphere in mid ocean is particularly rich in it. May we not attribute the cause of the beneficial effects of life in the open air, of a residence in the country, near the sea or in the mountains, and of long sea voyages to the larger proportions of this gas found in those regions? Schoenbein thought so, and after him many have adopted the same view—among them an English physician, Cook, according to whom a definite relationship prevails in India between cholera and other zymotic diseases and the proportion of ozone in the air, the diseases increasing when ozone decreases, and decreasing when the latter becomes more abundant. In consequence of the greater abundance of ozone in the atmosphere over the country and in proximity to living plants, it might seem advisable to advocate the presence of plants in apartments, instead of excluding them as some feel inclined to do, arguing that plants are living beings, that they breathe, and that, accordingly, they increase the ratio of carbonic acid. The view in favor of plants has been strongly advocated by T. M. Anders (House Plants as Sanitary Agents, 1887, Lippincott); but the most important point which should be established in relation to this matter, the fact that plants do really produce ozone, does not seem placed on a satisfactory basis. Proof is still wanting. And this brings us to face the fact that very little is known concerning the origin of ozone. We do not know whether any agencies are at work now in nature evolving ozone to any important extent. In the laboratory ozone may be produced by the electric spark, and when so evolved causes the particular smell perceived in the vicinity of electrical machinery; ozone is also evolved during the electrolysis of water. Are we then to assume that in nature ozone is produced by thunderstorms, those gigantic counterparts of our electrical discharge, and under the influence of the electric currents so frequently in operation in the atmosphere? Many chemists think so, and if this is the case it should be easily shown that the ratio of ozone to air is in fairly exact relationship to the proportion of thunderstorms, or to their recent occurrence. Ozone should be most abundant under the Tropics, should decrease in high latitudes, where thunderstorms are least frequent, and should be more abundant just after a thunderstorm than before. But none of these points have been satisfactorily established.

Without attempting to solve the riddle and to ascertain the origin of ozone, a French chemist, M. Hautefeuille, who ascribes the blue color of the heavens, or of the atmosphere, to ozone, asserts that this gas is more abundant in the higher than in the lower strata of our atmosphere. It may be so, at all events we are not much the wiser for

the assertion. While we know that ozone is nothing more than oxygen in an altered and allotropic condition, we are quite in the dark as to the methods by which this alteration is effected. We know that the ratio of ozone is very variable: that it is more abundant in May than in any other month; more abundant in the morning, from October to June, and in the evening, in July, August, and September, so that, upon the whole, it seems to follow fair weather and heat; but this hardly helps to solve the question, and much remains to be discovered.

Concerning ammonia, our information extends somewhat further than in the case of ozone. Ammonia is constantly present in the atmosphere. In 1857 Boussingault and, later, Schloesing, did good work in reference to this subject. They have shown that ammonia generally exists in combination with carbonic or nitric acid; only a small proportion is free. Its origin is easily ascertained, for ammonia is one of the by-products of organic putrefaction. Considering the amount of putrefaction which must take place on our planet, it is clear that this source is a fruitful one; and it must be added also that ammonia could not exist in an atmosphere where life was absent, nor in one where putrefaction was impossible, nor in an entirely aseptic atmosphere, the organisms themselves being aseptic. Although ammonia is a constant component, it is a very small one: air does not contain more than a few millionths of it; but water of atmospheric origin, rain, vapor, fog, etc., holds a larger proportion. M. Schloesing has devised ingenious apparatus and methods for ascertaining the proportions of ammonia in air and in rain water, as the matter is one of importance, particularly to agriculture, in view of the interchange of ammonia that occurs between air, rain, and ground water. One of the results has been to show that each hectare in France (something over 2 acres) receives yearly through rainfall, or from the atmosphere, 9.801 kilograms of nitrogen under the form of ammonia. This will be again referred to further on, when we come to consider the uses of this compound and its rôle in nature.

Other nitrogen compounds are also present in air—nitrous and nitric acids, for instance, both in very small quantities. It may be that they are formed under the influence of atmospheric electricity, as some experiments by Cavendish seem to show, and as indicated by some observations of Liebig, who detected nitrate of ammonia in the rain that falls during thunderstorms. It may be also, as Schoenbein suggests, that nitrous acid is formed by the action of nitrogen on water during the different oxidizations or combustions which go on rapidly in our works, factories, and so forth, and slowly in the field of nature. Nitric nitrogen is more abundant in and during winter, and it is more especially in rain water that its proportions have been ascertained. Generally some 0.73 milligram are present in each liter of rain water, and in France each hectare receives about 3.986 kilograms of this nitrogen through the rainfall. Added to the nitrogen received under form of ammonia, this gives us a total of 13.787 kilograms of nitrogen received by the soil.

Much of it is borrowed by plants. It has been observed in England and in France that rain water collected in cities or in their immediate vicinity contains more nitrogen (especially under the form of ammonia) than that collected in the country some distance away. Towns where industrial pursuits are thriving and active, where factories and furnaces keep their chimneys constantly at work, produce a large quantity of ammonia. London, Glasgow, and Manchester are specially noted for this. Some amount of carbureted hydrogen exists in the atmosphere (one ten-thousandth), and its name, marsh gas, gives a clue to its origin. Sulphureted hydrogen, also present in very small quantities, has its origin in some volcanoes and in the disintegrative processes going on in dead bodies or other lifeless organic materials. It is therefore often found in the vicinity of graveyards and of fecal matter. It is enough to merely mention the presence of a very slight proportion of boric acid, which is ejected into the atmosphere by volcanoes—by some at least.

Iodine has been detected in small quantities by Chatin, who is of the opinion that its presence or absence in the air and waters bears some relation to the occurrence of goiter in the human species. Very little can be said in support of this view. The atmosphere undoubtedly contains saline particles, and all observers who use the spectroscope have been more or less annoyed by the fact. But these particles are present under the solid form. They are positively in suspension in the air, and not under the form of vapor nor of gas. No very considerable mental effort is required to ascertain the origin of such particles. Dust pervades the whole atmosphere—that is, the lower strata at least—dust which has been torn from the soil in all countries of the world, in the deserts of Sahara, Kalahari, Gobi, or Atacama, in the lowlands, from the flanks of the mountain ranges, dust that has been poured out from the bowels of the earth by Cotopaxi and Kilauea, Vesuvius and Colima, Erebus, and Terror, and all this dust contains a large number of saline particles. The seas also contribute their share. The wind sweeps off the crest of the waves, blows the foam and brine inshore, often to considerable distances, with the result that the atmosphere contains a proportion of the salts of the sea, which often cover with a perceptible coating plants fairly distant from the shore. Farther inland the proportion of sea salts is decreased, but while not themselves apparent they exert apparent effects upon plants.[1] Another curious influence is exerted by these particles in quite a different direction. It is well known that aqueous solutions of salts may, under peculiar circumstances, be supersaturated; that is, may contain a larger proportion of dissolved salt than is consistent with theory. If air is allowed to come in contact with the surface, such a solution often suddenly crystallizes. M. Gernez, who has thoroughly investigated these phenomena, comes to the conclusion that the sudden crystallization is due to the presence

[1] Cf. P. Lesage: Influence du bord de la mer sur la structure des plantes.

in the atmosphere of a few particles of the corresponding salt, for it is a familiar fact that if the very smallest amount of a salt is dropped into a supersaturated solution of the same salt, the latter instantly crystallizes, just as a loaded gun goes off when the trigger is pulled. If this interpretation be correct, certainly air contains a large amount of sulphate of sodium, for supersaturated solutions of the latter crystallize very easily when not protected from contact with the general atmosphere. A fact that favors this explanation is that when the air in contact with a supersaturated solution is carefully filtered through a plug of asbestos or cotton it has no longer the power of inducing crystallization. It has been deprived by the plug of those particles which, by their conformity to the composition of the solution are able to induce the phenomenon referred to. If this explanation of M. Gernez is correct, the constant refusal of a supersaturated solution to crystallize when in contact with the general atmosphere would prove that the salt which it contains is not to be found free in the air. At all events, the interpretation is quite plausible and the fact is of interest.

Before dismissing this brief review of the main chemical constituents of the atmosphere, a word must be said concerning the volatile organic matters which Brown-Séquard and d'Arsonval thought they had found in expired air a few years ago. These two physiologists, collecting air expired by men or animals, and condensing, by means of cold, the aqueous vapor always present in such air, obtained a liquid to which they ascribed toxic properties. If such liquid is injected under the skin of an animal, it kills more or less rapidly, the results varying according to dose, the species experimented upon, and other circumstances. The inference was that expired air contains certain volatile substances excreted or exhaled by the lung surface and dissolved in the water derived from the condensation of pulmonary aqueous vapor, and from which they may be isolated by analysis. A very tempting inference, to be sure, for it seems clear that confined air vitiated by respiration, even after it is deprived of carbon dioxide, remains heavy, unpleasant, unhealthy, and even injurious, and if it has an unpleasant smell, the reason is probably because it contains peculiar organic matters. Do these matters—whose existence is suspected, not proven—accumulate in the liquid condensed by Brown-Séquard and d'Arsonval, and impart to it its toxic properties? The one great difficulty in answering this question is the fact that the different physiologists who have endeavored to repeat and confirm the above experiments in France, Germany, and Italy, have been unable to obtain the same results. They have not succeeded in obtaining from the breath any condensed liquid which had a toxic influence, and the most probable explanation is that some mistake was made by the original observers. When care is taken to exclude all elements except those derived from the breath no ill effects are observed on animals. It may very well have happened

that Brown-Séquard and d'Arsonval did not take pains enough to prevent the contamination of the liquid, either by solid, and probably living, particles of nasal or buccal origin, or by impurities belonging to the apparatus and receiver in which condensation was effected. We can not, therefore, accept their original statement although there is a probability in favor of its truth. Further experiments are required to settle the matter.

III.—Biological Rôle of the Chemical Constituents of the Atmosphere.

Having now considered the constituents of the atmosphere, their relative proportions in the aerial mixture, their mode of production and distribution—that is, their mode of equilibration—and taking it as an established fact that the composition of air varies but slightly, remaining constant within the limits previously mentioned; having also briefly reviewed the part played by animate life in maintaining the composition of the atmosphere, we may now proceed to consider the chemical and physical influence of the atmosphere on the life of organisms.

For the sake of convenience and clearness, we shall begin with the chemical influence, and review in turn the influence of each separate constituent.

The life-maintaining gas of atmosphere, *par excellence*, is, to all appearances, oxygen—and we shall deal first with this element.

That its presence in air is indispensable for the proper execution of the respiratory functions is a fact familiar to all. Physiology has most clearly demonstrated, for a century past, the great importance and usefulness of this gas. It is essential to respiration. Man consumes large quantities of it.[1]

Inspired air, containing on the average 20 or 21 per cent of oxygen by volume—expired air containing only 16 per cent—4 per cent have, in consequence, been absorbed by the organism, and in twenty-four hours

[1] It should be noticed that neither men nor animals ever breathe pure air, nor can they do so under normal and natural circumstances. The reason is obvious. The lungs are never totally emptied. Even after the deepest expiration, there remains in the lungs and air passages a residue of air that can not be expelled (owing to the anatomical impossibility of total pulmonary contraction), and such air is vitiated and unfit for respiratory purposes. The next inspiration brings a certain amount of pure air, but, as a matter of course, it mixes with the impure residual air, and therefore becomes vitiated to some extent. The only parts which receive strictly pure air are the superior air passages. At the end of expiration they are full of impure air; but the very first result of inspiration is to return all this impure air to the lungs, and to fill the air passages with pure air. A part of this goes to the lungs, and all that remains in the nose, trachea, etc., is pure. All mucous membranes have some respiratory functions, so that a proportion of this pure air is used; but the most important of the respiratory organs is bathed in a vitiated atmosphere, and one may truly say that neither men nor animals ever breathe really pure atmospheric air. A very simple and ingenious experiment has

an average adult retains over 740 grams, or 516,500 cubic centimeters, a total amount of 500,000,000 cubic meters per day for the whole of mankind. The amount of oxygen required varies somewhat according to sex and age within the limits of the same species. During childhood and old age less is needed than during the prime of life. An adult may require 910 grams in twenty-four hours: an 8-year old child is content with 375. Various circumstances, such as vigor, health, temperature, rest, exercise, and so on, increase or diminish oxygen consumption. This oxygen is absorbed in our tissues, which it reaches chiefly through the agency of the lungs and blood; a small proportion, however (one-eightieth of the amount absorbed by the lungs), is absorbed by our skin, which has, therefore, some respiratory importance.[1] All our tissues need oxygen: all breathe. For it must not be forgotten that the lung is nothing more than an instrument in the respiratory process; the chemical operation which is the essential part of this function takes place elsewhere, in the tissues themselves. The lung is only the door by which oxygen enters the system. Physiologists held quite different views a century ago, and Lavoisier himself supposed that the main act of respiration takes place in the lung. What really happens is that oxygen, introduced into the lung, filters through the very thin walls of the pulmonary capillaries, where it finds in the red blood corpuscles a substance called hemoglobin, with which it unites to form a compound which bears the name of oxyhemoglobin. A very unstable compound it is, for throughout the tissues, in the capillary vessels of the whole body, oxygen is allowed to escape and effect its work among the cells. Numerous and complex reactions take place, and one set of them results in the formation of carbonic acid. The blood, therefore, is nothing more than a vehicle: it carries oxygen to the tissues and brings back to the lungs carbonic acid, which, if not allowed to escape, would soon cause death. The "organic combustions" do not occur in the lungs, as was thought a century ago: their seat is in the tissues, throughout the whole body.

While respiration is common to all animals, it is not equally active

been devised by Prof. Charles Richet in order to give an experimental proof of the soundness of this inference. All that is required is an india-rubber tube, some 2 or 3 yards in length, of rather wide bore. This tube is so adapted to the respiratory apparatus of a dog or rabbit, that by some means or other he is made to breathe through it. Under such conditions death from asphyxia soon results. This experiment merely exaggerates the normal conditions; adding the tube amounts to nothing more than lengthening the air passages, and putting a greater distance between the lung and the atmosphere. The result is not a matter of surprise—external air can not reach the lungs. Inspiration is not sufficient to draw to the lung the whole of the air contained in the tube, plus a sufficient amount of pure air. Each inspiration introduces some fresh air in the end of the tube, each expiration expels it, and none reaches the animal, which is unceasingly breathing the same air over again and perishes from asphyxia, although in appearance breathing as freely as possible.

[1]Cutaneous respiration is quite sufficient, in winter, to maintain life in some animals; the frog, for instance.

in all; it is more intense in birds than in mammals; more intense in mammals than in reptiles and mollusks. An active animal will consume more oxygen than one that is slothful, sleeping, lethargic, or hibernating. Yet all animals breathe; none can dispense with oxygen, and if that gas fails them they die.

It is the same with plants. While for their nutrition they exhale oxygen (chlorophyllian function) during the day, under the influence of light, they breathe at all times, absorbing oxygen and exhaling carbonic acid, as Priestley has shown. Here, also, the intensity of the function may vary. Plants need a great amount of oxygen during germination, and this explains why many seeds can not germinate under water, where the access of oxygen is retarded and inadequate, or in compact soil, where air—oxygen—is also deficient. One sort of seed requires the hundredth of its weight in oxygen, another is quite satisfied with ten or twenty times less; but all need oxygen, as De Saussure proved nearly a century ago.

Plants also need oxygen for their growth, and at the flowering period they use a large amount of it, chemical operations being then so very rapid and intense that a quite perceptible heat is given out. During all moments of their life, from birth to death, plants breathe. Separate parts, such as leaves, twigs, flowers, fruits, need and use oxygen also—they are not dead; and a nosegay in a room plays its part in the withdrawal of oxygen as well as the person sitting at the table, the cat sleeping near the hearth, the lamps, the fire. A fruit or a leaf, in any closed receiver full of air, alters the composition of the latter, withdrawing oxygen and giving carbonic acid in its place.

In brief, without oxygen there would be no life, no animals, no plants; the whole planet would be one desolate landscape of rocks and sand, from which the solar heat would in vain strive to elicit the merest blade of grass, the smallest insect.

Such being the case, some might incline toward the opinion that life is abundant and intense in proportion to the amount of oxygen, while, where air is deficient, life also is wanting. Logical extremes are, however, almost invariably absurd, and the researches conducted during the last twenty years, by Paul Bert and Pasteur especially, go to show conclusively that both opinions are equally erroneous.

Living beings, as they are at present, are adapted to life in an atmosphere containing one-fourth oxygen and three-fourths nitrogen. Experience shows us that if the ratio of oxygen is decreased even by one-fourth, life can no longer be maintained. The adaptation of organisms to the atmosphere is thus very close, and this suggests the idea that perhaps a change in reverse direction might also be injurious; that an increase in the ratio of oxygen might prove harmful. Paul Bert has thrown much light on this question, and his experiments have amply proven a fact which at first sight seems most improbable, but is less surprising to those who always keep in mind the fact that living

beings are adapted to their environment, and that the adaptation is often very strict. He has shown that oxygen—the vivifying gas *par excellence*, that which is essential to life—is also a violent poison; a poison for plants as well as for animals, for the cells and the whole organism. All that is required is for oxygen to acquire a certain tension in the atmosphere or—what amounts to the same—be present in a certain ratio above the normal, and it becomes an agent of death. This can be demonstrated in two ways. Animals or plants may be made to live in a normal atmosphere, but under higher pressure than the average; or, again, they may be placed in artificial air where the ratio of oxygen has been increased. In both cases the phenomena are similar; in both, death is the result. While a satisfactory explanation has not yet been proposed in the case of plants, Paul Bert has been able to show that animals die in a superoxygenated atmosphere as soon as their blood contains one-third more than the normal ratio of oxygen, because, in such an atmosphere, the hemoglobin of the red blood corpuscles is saturated with oxygen—a fact which never occurs under normal conditions—and a proportion of this gas then dissolves in the serum of the blood itself. The oxygen dissolved in the serum does all the harm. The tissues can not withstand the presence of free uncombined oxygen; they are killed. This is the *quo modo* of the phenomenon. The *quare* is yet wanting: Why do the tissues require combined oxygen, and why does free oxygen kill them? Here is a riddle for physiologists: it is one worth their pains and trouble.

Now, it must be said that while a certain increase in the ratio of oxygen results in death, lesser increases of a temporary character may be beneficial. Every poison kills, doubtless, but there are doses which not only do not kill, but even confer benefit and improve health. This toxicity of superabundant oxygen is undoubtedly one of the most curious facts that recent years have brought to light, and it is a very positive and demonstrable one.

On the other hand, to say that without free oxygen there can be no life would be incorrect. Pasteur's investigations have shown that if some micro-organisms can live only where air and oxygen are present, others, which have been termed anaerobic, much prefer an environment where air is wanting. Such is the case with those which cause fermentation. They induce fermentation only when in a medium devoid of oxygen, and, as Pasteur put it, fermentation is a consequence of life without air. What then occurs in a fermenting medium? A particular kind of microbe—each fermentation is due to a particular sort or species of microbe—is conveyed, by air, by water, or is purposely introduced, into that medium. During a time it lives there upon the oxygen which it finds. At last oxygen fails; all the provision has been expended, and diffusion has not taken place rapidly enough to meet the needs of the micro-organism. The latter has then to shift for itself in some manner. Free oxygen is wanting, to be sure, but nevertheless there is oxygen

to be had—oxygen in combination with one or the other of the substances dissolved in the liquid under consideration. This the micro-organism uses for its wants. It withdraws this oxygen and releases it from its fetters—not for the benefit of oxygen certainly, but for its own advantage. As this release can not be effected without releasing also at least one and often many other constituents which were combined with the oxygen, they also are freed, and their escape is one of the characteristic phenomena of fermentation. Let us take an instance, that of alcoholic fermentation. This requires water in which cane or grape sugar is dissolved (cane juice or grape juice). The microbe removes from the sugar a portion of its component oxygen, thus decomposing it into free carbonic acid and alcohol. This is one instance among a hundred. In all the process is fundamentally the same. In all processes of fermentation a microbe is present which, unable to otherwise obtain its requisite supply of oxygen, takes it by decomposing the surrounding substances, changing them into new compounds, containing in part the same elements as the original but differently united. So we see that, upon the whole, anaerobic micro-organisms, which seem more or less to shun free oxygen and air, do really breathe oxygen, as other organisms are wont to do. Thus, so far as some organisms are concerned, life is not impossible where free oxygen is wanting; and, on the other hand, wherever life is present, some method exists by which oxygen may be secured. While anaerobic micro-organisms seem to be exceptions, they fall under the general law that living organisms must have oxygen.

Between such anaerobic organisms and those which need free oxygen many transition forms exist. It will be sufficient to recall the fact that vegetable cells are aerobic and anaerobic simultaneously, since they can produce alcoholic fermentation. "Let us place a beet root in carbonic acid," says Duclaux, "we shall see it produce alcohol. Cherries, plums, apples, all fruits containing sugar, entire sacchariferous plants, under the same circumstances do the same. Their sugar is in part broken up into alcohol and carbon dioxide. The only difference between these cells and those of yeast is that the former are less suited for anaerobic life, and the fermentation which they effect is less complete than that effected by yeast, and they stop or die before all the sugar has been transformed. But such differences are only differences in degree."[7] If we now turn to animal cells, we find that they are also, in fact, anaerobic. Have we not seen that free oxygen dissolved in the serum of the blood is toxic, and that it kills? That the tissues do not breathe pure or free oxygen, but require to have it offered to them combined with hemoglobin? And what is this, if not true anaerobiosis?[1] Hence we must draw the inference that while all

[1]The notion that animal cells are anaerobic was propounded by Pasteur. A. Gautier, in 1893, took it up with some valuable arguments and experiments. These experiments have shown that quite a number of well-known disassimilation products

living organisms require oxygen, and must have it, a large number at all events require to have it offered to them in a combined form. All animals seem to prefer combined oxygen. As to plants, we are in the dark. Certainly free oxygen enters the stomata; but is the oxygen used as such by cells, or does it previously form some compound with some liquid in the plant? We do not know. What we do know, however, is that on our planet and under the present laws of organization and life where oxygen is wanting life is also wanting, and that where oxygen is in excess of the normal ratio life is impaired and after a time destroyed. Such is the main conclusion to be kept in mind.

We will now consider nitrogen, or azote. The name is significant. It means that this gas is not adequate to maintain life, for we all know that if an animal or plant be placed in an atmosphere containing nitrogen only, death ensues in a very short time. It should not be inferred that nitrogen is toxic. We inhale a large proportion of it without the slightest inconvenience: but it is inert, and neither burns nor maintains combustion. Its only function in respiration seems to be that of a diluent or moderator. Pure oxygen would be certain death, while, diluted with some amount of nitrogen, it is absorbed only in the requisite proportion. Nitrogen here plays the part of water added to wine—a useful part, most certainly, since we could not do without this diluent—but a negative one. But what more could be expected of an inert gas?

There is, however, a much more important part played by nitrogen in the economy of nature. It is abundant in organisms. It forms a large proportion of our frame and tissues and is most abundant in the atmosphere. Lastly, as shown by Magendie, when animals are deprived of food containing nitrogen, they die. Let us start from this well-established fact, that nitrogenous food is necessary to maintain life in animals—in higher animals at least. This nitrogenous food is, in the long run, provided by plants. While a few plants—lentils, for instance—yield fruits containing a large proportion of nitrogen, the greater number furnish nitrogenous food only by undergoing the transformations which animal digestion effects upon vegetable food—grass, hay, leaves, etc. Some animals require nitrogen in the form of meat, while a greater number are content with that contained in plants; but, upon the whole, nitrogen is always primarily provided by plants. Now, as nitrogen is essential to all animals, how do the plants which provide it manage to incorporate it? Where do they get it?

The soil contains some amount of nitrates, a proportion of which it is quite certain that plants absorb, for cultivation always impoverishes the soil, deprives it more or less of nitrogen, as chemistry shows, and in order to restore its fertility nitrogen must be added to it under

which are found in the blood, in the urine, etc., are produced by the cells of the tissues after circulation has entirely ceased when air and oxygen are no more brought to them. The inference is that animal cells are, according to circumstances, aerobic or anaerobic.

the form of nitrogenous manures. But notice must be taken of the following facts. In the first place, forests—whose age is often very great—go on growing, although for centuries no manure has been added to the soil on which they grow, and the same is true of pasture land. Again, it is a well-known fact that if soil is manured with any nitrogenous manure, it yields more nitrogen in the crop than was given to it in the fertilizer. These facts, ascertained by Boussingault many years ago, suggested the idea that atmospheric nitrogen might play some part in the nutrition of plants, and that in some way or other they might borrow nitrogen from the atmosphere which contains such an amount of this substance.

To be sure, the atmosphere contains some ammonia (nitrogen and hydrogen combined), but the amount is very small. Mayer, of Heidelberg, while cultivating in the open air plants whose roots were immersed in nutrient solutions from which nitrogenous compounds were excluded, and protecting them against rain so as to exclude the influence of such nitrogenous compounds as exist in rain water, obtained a crop containing exactly the same amount of nitrogen as the seeds from which the plants grew—not a milligram more. This shows that the amount of ammonia, or other nitrogenous compounds, which may be borrowed from the atmosphere by plants in a direct manner is quite insignificant. But while plants may obtain very little or nothing from the atmosphere by direct process, the case is entirely altered when indirect processes are allowed to operate. Under such circumstances atmospheric ammonia when combined with the elements of the soil, plays an important part, as shown by Berthelot. Instead of remaining useless, as when contained in the atmosphere, it then becomes useful, and is utilized by plants. This process by which atmospheric ammonia combines with soil elements is not a spontaneous one such as that by which hydrogen burning in oxygen forms water—there is no unavoidable chemical reaction—it is effected by the agency of definite micro-organisms. While a specimen of soil left to itself under normal circumstances acquires more nitrogen, the same specimen remains unaltered (neither loses nor acquires nitrogen) when it has been previously sterilized by subjecting it to a heat above 105° or 110° C., by which all micro-organisms are killed. Again, M. Schloesing and Muntz have shown that it is by different micro-organisms that the nitrogen contained in nitrogenous organic matters of arable land is made to combine with other matters, and to form nitrates. One generates ammonia; another transforms ammonia into nitrous acid, which forms nitrates by combining with basic elements, and lastly a third micro-organism transforms the nitrites into nitrates; and this triple process is what is called nitrification—an operation fully investigated by Munro, Winogradsky, and Frankland.

Thus, by one means or another, atmospheric ammonia may be put within reach of plants and be used by them. But ammonia is however a very small proportion of the nitrogenous contents of the atmosphere.

Is there no other supply, and especially, is there no method by which pure atmospheric nitrogen may be also utilized by plants? In view of the considerable amount of nitrogen contained in atmosphere, the matter is one of great importance to plants.

The question has been answered by Hellriegel.[1] After twenty-five years' investigation, the learned director of the agricultural station of Bemberg has finally proved conclusively that certain plants at least have the power of assimilating atmospheric nitrogen. These plants belong to the leguminous family. While cereals, for instance, need to be provided with nitrogen under the form of nitrogenous compounds mingled with the soil, or under the form of nitrates or ammonia salts, lupines, pease, clover and such plants do very well without such compounds. And yet they contain nitrogen; moreover, agriculturists know that they not only do not require nitrogenous manure, but that after they have been grown on a soil they contain more nitrogen than the soil could possibly have furnished; hence the name of "bettering plants." If they are buried in the soil, they not only restore the amount of nitrogen which they may have derived from it, they add to it an excess which they have obtained elsewhere; that is to say, from the atmosphere. Plants grown in a soil totally deficient in nitrogen contain much more of it than the seeds from which they spring—provided, however, one condition is fulfilled. This condition is that the roots possess certain peculiar outgrowths or small tumors—nodules, as they are commonly called—in which a special sort of bacteria is found. If the bacteria are wanting, the plant does not grow well; it remains puny and deficient in nitrogen, but if watered with water to which has been added a culture of the requisite species of bacteria it becomes thrifty and yields an amount of nitrogen amounting to a hundredfold the weight contained in the seed.

It seems that in different species of leguminous plants the active and important species of bacteria are different. That which is adapted to acacia, for instance, although it does not suit pease, works well with beans, and vice versa. Are we to draw the inference that each species of this family has its own special bacterium? Nobbe is not of this opinion; he thinks there is only one species, which he calls *Bacterium radicola;* but that within this species a number of races or varieties has been evolved, each one specially adapted to a sort of communalism with a particular species of plant. For instance, if one individual of this bacterium lives in the nodosities of one particular plant, its progeny becomes specially adapted to life on the same species, and does not thrive on another species. Such is Nobbe's view briefly summarized, and it would explain many curious facts noticed by

[1]Hermann Hellriegel, born 1831, died September, 1895. This important work was accomplished with the cooperation of Mr. Wilfarth, and was made known in 1886 at the Naturforscher-Versammlung in Berlin. Varro and the old Roman farmers had noticed that beans, lupines, and vetches render the soil more fruitful, but Hellriegel and Wilfarth discovered the reason.

agriculturists and horticulturists concerning sympathies and antipathies between plants, and like matters.

The quantity of nitrogen which leguminous plants can obtain from the atmosphere by means of the bacteria which live on their roots may be very considerable; it may amount to 100 or 150 kilograms per hectare (2½ acres). Hence, it is an excellent plan with soils deficient in nitrogen to grow and turn under leguminous plants. It follows also that if a given soil seems unfit for the culture of a particular leguminous plant, this may be because it does not contain the necessary bacteria, and under such circumstances all that is required is to inoculate it. A culture is not required; it is enough to sprinkle some earth taken from a field in which leguminous plants of the same species have grown and thriven. The bacteria abound in that earth, and at once multiply in the field. This is no matter of mere laboratory experiment; the process has been tested on a large scale at Meppen in Germany, by M. Salfeld, with the best results, the crop having been then doubled and trebled.

This inoculation may be performed in another manner. M. Bréal, of the Paris Museum of Natural History, grows two lupines in separate pots, filled with sterilized earth. He inoculates the roots of the one with a needle dipped previously in a culture of the appropriate bacterium, while the other is not inoculated. The result is that the former thrives, while the latter remains puny and perishes.

Besides, Schloesing and Laurent have shown that if different leguminous plants are cultivated in a confined atmosphere the amount of nitrogen in the air decreases.

The general result of the very important labors of Hellriegel and Wilfarth, of Nobbe, of Sir John Lawes and Sir Henry Gilbert is, then, the discovery that different plants of the leguminous family—belonging in particular to the papilionaceous division—are endowed with a very special mode of nutrition, quite different from that of other phanerogams. By means of the cooperation of a few micro-organisms which dwell in and on their roots, they are enabled to draw free nitrogen from the air; not ammonia, nor any other form of combined nitrogen, but free nitrogen, which is used as a nutriment. And thus it happens that that enormous quantity of nitrogen which goes to make a large proportion of the atmosphere, instead of being useless as it seemed at first, is of very great importance to plant life. The probabilities are that it is even greater than it now appears. We feel it difficult to conceive that only a small proportion of plants are able to avail themselves of this source of nitrogen, and physiology teaches us that so far as the principal functions of life are concerned there reigns great similitude in the processes by which they are effected. That papilionaceous plants only, of the whole host of the vegetable world, should be able to acquire nitrogen in the manner described seems unlikely, and thence the opinion that a similar process and a similar function must obtain

among other families of plants. This is but an hypothesis, however, and no definite statement can yet be made concerning this attempted generalization. Some facts, indeed, go against it, and show that certainly not all plants have the functions which we have noted in the papilionaceous family. Messrs. Schloesing and Laurent infer from experiment that some species at least are unable to make use of atmospheric nitrogen, and require to have it provided to them under the form of different compounds contained in the fragments and débris of other plants, which thus play the part of manure and food. While the lion and tiger eat the sheep and deer, some plants eat, so to say, their congeners, and exhibit a form of cannibalism. The latter obtain nitrogen from the atmosphere, and after death their remains serve as food for other plants. Such is the case with mosses and many cryptogams. So, observe the gradation: Inferior plants[1] draw nitrogen from the atmosphere; superior plants feed upon the remains of the lower;[2] and, lastly, animals feed on other animals or plants. Man eats both animals and plants, and crowns the edifice of life, as he supposes; but the solid substructure upon which all the building rests is merely an agglomeration of humble unnoticed forms, often invisible to the naked eye, whose functions are to provide the animal and vegetable kingdoms with an essential part of their food. Whether there is here a plan is not for me to decide, but most assuredly the connections and interactions are of interest.

This exposition may seem somewhat long, but it was necessary. It shows that certain plants, at least, can either directly or indirectly fix atmospheric nitrogen without having recourse to the nitrates of nitrogenous manures. Here again it is shown that air is indispensable to life. A gas that at first seems inert and useless is found, after careful investigation, to play a most important part in the nutrition of living organisms. Without nitrogen there would be no plants, no food, no animals, no mankind, in brief, no life at all. And if atmospheric nitrogen were to disappear, life would soon be extinguished. Who, then, will consider this element of the air as useless?

We now come to carbonic acid.

We all know that it is an essentially noxious compound, and doubtless there is little in its history to redeem its reputation. One-half of our respiratory function is concerned especially with the task of ridding

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[1] And some superior plants also, such as those of the papilionaceous group; but even with them the process is indirect, as it is through very low organisms (bacteria) that nitrogen is brought to them.

[2] When Melchior Treub visited Krakatoa after the disaster of 1881, in order to investigate the floral repopulation of the island—seeds being brought by currents and winds from the surrounding parts in abundance—he noted that the first plants to appear were algæ and lichens. And it was only some time after the latter had taken a foothold, and, so to say, prepared a suitable soil, that higher plants were seen, and lastly phanerogams. This progression is quite in accordance with physiological facts.

our body of this substance, which is unceasingly generated in our tissues. It is not fit for breathing purposes, and all animals and plants perish in a confined atmosphere when the proportion of this gas rises above a very limited ratio. An atmosphere which contains one per cent carbon dioxide has evil effects upon most organisms, and when the ratio is ten per cent, life is endangered and death only a matter of time. Carbonic acid is of no use at all to the tissues, and when we breathe in an atmosphere where this gas is abundant, the blood corpuscles are not able, in the lungs, to get rid of the carbon dioxide they have collected in the body; so they keep it, and, keeping it, they can not take with them the amount of oxygen necessary for the cells and tissues. It may be asked why they keep the former. The reason is that gas exchanges between the blood and the atmosphere depend upon the amount or tension of the gas in both media. As soon as the tension of carbonic acid in the atmosphere is greater than that of the same gas in the blood, the blood corpuscles retain their carbonic acid. If the amount of carbonic acid in the atmosphere is increased, its tension becomes at some point superior to that of the same gas in the blood corpuscles. These, then, retain the noxious gas which takes the place which should be abandoned to oxygen. The result is death by asphyxia. Before death supervenes a condition of anæthesia is induced, which Bichat specially investigated by means of an ingenious experiment, through which the venous blood—well provided with carbonic acid, of course—of one animal was made to pass into the carotid and cerebral arteries of another, so that the latter had its brain irrigated with asphyxic blood, and was brought to a condition of anæsthesia. Even when applied locally to the surface of the skin, carbon dioxide induces a state of local and temporary insensibility, a fact which seems to have been long known and frequently utilized. Pliny relates in his Natural History that marble (carbonate of lime), when mixed with vinegar and placed upon the skin, puts the latter to sleep, i. e., renders it insensible, so that it may be cut and burned without inducing pain. In this case the anæsthetic agent is carbon dioxide, which is set free by the action of the acetic acid of the vinegar upon the carbonate of lime.

When carbon dioxide acts upon the entire organism, as when it is inhaled by the lungs, it induces general anæsthesia. This has been investigated by a number of physiologists, and one among them, M. Ozanam, has found it so satisfactory that he feels no hesitation in commending it as a substitute for ether or chloroform. His advice has never, to my knowledge, been followed by surgeons or physiologists, and some doubt may be expressed as to the expediency of using for surgical or other purposes so dangerous an agent. Some cases are known in which man has been deeply under the influence of carbon dioxide without fatal results. In such circumstances, anaesthesia has been complete. The patients relate, at least some of them, that before becoming unconscious there occurs a delightful condition during which

they seem to be surrounded by a host of very brilliant lights, while exquisite music is played by some invisible orchestra. But this state is of short duration, and total unconsciousness soon occurs, which, if the toxic gas keeps on accumulating in the blood, is rapidly converted into eternal sleep. Cases of death by carbonic acid are not infrequent; they are met with particularly in the vicinity of fermenting liquids, such as brewers' vats or wine cellars; in places where carbon dioxide is naturally exhaled by "gas springs;" by thermal springs in some caves or grottoes, and in all ill-ventilated rooms where a proportionately large number of men or animals are gathered. In lecture and assembly rooms, which are often crowded, air vitiates rapidly; in theaters, in schools, in lecture halls, as much as 10 parts per thousand of carbonic acid has been observed, and in Alpine stables, as before referred to, where animals and men were crowded together, each seeking some warmth in the close vicinity of his neighbor, the ratio of 21 parts per thousand has been recorded.[1] Such atmosphere is toxic,[2] and proofs thereof are not wanting.

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[1] M. G. H. Richards, of the Massachusetts Institute of Technology, has, during nine years past, made some 5,000 analyses of the air of lecture rooms. The normal average proportion of carbonic acid in external air is between 3.7 and 4.2 per 10,000. In buildings, the proportion increases according to circumstances. For instance, in empty rooms it is higher by 0.5 on the average in consequence of the decomposition of organic matter, which always remains after the passage of any number of human beings, in the cracks of the floor, on the walls, etc. In the parts of the building where people come and go, without stopping for any considerable time, the ratio is a little higher, and becomes 5 per 10,000. In lecture rooms things are at the worst, as might be expected, and the ratio is 6 or 8 and occasionally 10 or 12 volumes of carbonic acid per 10,000 of air. If such proportions are exceeded, work becomes difficult and unprofitable. Each adult exhales, on an average, according to Andral and Gavarret, some 22 liters of carbon dioxide per hour, so that a man breathing in a confined space 3 meters long, 2 meters high, and 2 meters wide would in twenty-four hours transform the whole of the air of this space into an air having exactly the composition of that exhaled from the lungs. It must not be forgotten that each gaslight, on an average, produces 128 liters of carbon dioxide per hour, and 10 grams of candle produce 14 liters. Under such circumstances no one can wonder that the atmosphere becomes so soon vitiated in rooms where any considerable number of persons are assembled.

[2] It is toxic in its natural condition, by which is meant, if oxygen is present in it only in the usual proportion. But, experimentally, such atmosphere may be prevented from becoming dangerous if its composition is altered by an addition of oxygen. Regnault and Reiset have seen dogs and rabbits live in an atmosphere containing 25 per cent carbon dioxide, 30 to 40 per cent oxygen, and about 40 per cent nitrogen. Even without increasing the ratio of oxygen, animals may live a short time in an atmosphere containing a large proportion of carbon dioxide—30 per cent, for instance, oxygen being 16 per cent (Le Blanc): and Snow has seen birds withstand some time the effects of an atmosphere containing 21 per cent oxygen, 59 nitrogen and 20 carbonic acid. But these experiments can not have any considerable duration, and the average limit of respirable atmosphere is set by the composition of expired air. An atmosphere containing 4 per cent carbon dioxide, 16 per cent oxygen, and 80 per cent nitrogen is inadequate to long maintain life. A lamp is soon extinguished in such an atmosphere, but man may live in it for a short time.

To avoid any danger of the vitiation of air, hygienists are agreed that more is

For instance, during the wars in India, 146 prisoners were one evening at 8 o'clock shut up in a small room. Out of the number only 50 were still living at 2 o'clock next morning, and at daybreak only 23, all dying. Again, after the battle of Austerlitz, out of 300 prisoners confined in an ill-ventilated cellar, 260 died in a few hours through asphyxia, induced by an excessive proportion of carbon dioxide. And at the celebrated Oxford assizes (the "fatal" or "black" assizes in 1577), the high sheriff and 300 other persons died suddenly in court from asphyxia induced by the same means. It may be that in these cases some other influence was also at work, and that some exhaled substance similar to that which Brown-Séquard and d'Arsonval thought they had detected, added its influence to that of carbonic acid; but the existence of this substance has not yet been proved, although it seems probable.

Other cases of poisoning by carbonic acid are met with in natural conditions. Men and animals are occasionally killed by such gas, exhaled by neighboring springs and accumulated in hollows or small valleys. Such "death valleys" have been described by many travelers. No plant is seen, not a blade of grass, not a shrub or tree. The soil is bare, stony, laid as if struck with death. Here and there a skeleton is perceived bleaching in the sun—a skeleton of bird, mammal, or even man. Ignorant of the fatal properties of the valley, animals or men

required than the 10 to 20 cubic meters of air per individual per hour, that was generally considered sufficient. In the most ventilated hospitals of Paris 100 cubic meters are provided, but under normal conditions 60 are quite enough for persons in good health. As a rule, the atmosphere of a room may be considered as vitiated as soon as it begins to smell close. When this happens, however, it must not be considered as due to the smell of carbonic acid itself, which is scentless. The smell of close air is due to organic substances—hitherto undefined, or only partly known—which are exhaled by men and animals, and probably more by the skin and its impurities than by the lungs themselves, and generally the amount of these substances is considered as roughly proportional to the amount of carbon dioxide met in the air. Smell is considered as indicating approximately the unhealthiness of the atmosphere as regards respiratory purposes, and is a safe enough criterion. When a room becomes close, it should be thoroughly ventilated, and in such case a draft should always be established, two doors or windows, on different sides of the room, being opened. One is not enough: both are required in order to completely expel the close air and replace it by pure. Generally servants—and masters as well—are content with imperfect ventilation. Such is especially the case in winter, when air is often vitiated by the presence of a gas, carbon monoxide, which is given off in very small quantities by defective heating apparatus, stoves especially. Although this gas is never present in any great quantity, it is a source of considerable danger; and in countries where slow-combustion stoves are used, it is each year the cause of many deaths. Carbon monoxide has a greater affinity for hæmoglobin than has oxygen. It therefore combines with it and thus there is no place left in the blood corpuscles for oxygen, and the blood then carries no more of the latter gas to the cells and tissues of the body. This gas is also found in the air of mines, but in the open air is not met with, or occurs in such small quantities that it can not be detected by present methods.

have wandered there while in pursuit of food, and in the lower part, where the influence of wind is the least and where the heavy gas naturally accumulates, asphyxia rapidly ensues. None who enter come out alive, and the bird of prey soaring in the heights, whose keen eye perceives the victim in the death struggle, and who pounces down upon this welcome opportunity, is vanquished in turn and rises no more.

Fatal to animals as well as plants, expelled by both from the organism as soon as it is produced, carbonic acid appears to all under the feature of a death-dealing agent, as a gas whose toxicity is unquestionable. The only word that can be said in its behalf is that at the moment of death it may act a kindly part. Death in the majority of cases, as a consequence of disease, is induced by asphyxia. During the death struggle respiration fails gradually, becomes slower and more superficial, with the inevitable result that carbonic acid accumulates in the blood. It is probable that when man is about to fall into his last slumber, when the body is on the point of entering that final stage of dissolution and disintegration which we call death, carbonic acid intervenes and plays its part, slowly drawing the curtain, gently putting intelligence to sleep, rendering it unconscious, deaf to sound, insensible to pain, and by beneficial and kind anæsthesia easing the final act of physical life. This may well be so, and this gas which some physiologists consider one of the agents by which each of us is brought into the world by stimulating the contractions of the maternal womb, thus also assists us out of it.

This function, however, is not the only beneficial one which carbonic acid fulfills, and concerning that very unwholesome and toxic constituent of the atmosphere much remains to be said. The unfavorable features have been put in full light; it is but fair to do the same for the redeeming traits, and this shall proceed to do.

All animals directly or indirectly feed upon plants, and plants draw from the soil the greater part of their mineral constituents. Nitrogen and oxygen they borrow from the atmosphere. But what about carbon? The matter is important, as their frame and tissues contain a large quantity of this substance. Two sources are available. Carbonic acid—carbon combined with oxygen—is present in the soil, where it is to be found combined with different substances in the form of carbonates, and in humus, the superficial layer of the soil, made up of fragments of leaves, of branches, of roots dead and decomposed, of mosses, dead ferns, etc. But we can not take into account the carbon which exists in humus, as the first plants which appeared could not have made use of it. There remain the carbonates of the soil, and it would seem to follow that this must be where plants obtain the larger amount of the carbon they use, as Mathieu de Dombasle and many other agriculturists after him supposed. A number of experiments by Sprengel,

De Saussure and others, have shown, however, that the part played by carbonates is less important than was thought, and more recently Liebig has established the fact that plants grow and thrive quite well in a soil whence all carbonates have been expelled. Where then do they get their carbon? We know now that they take it from the atmosphere. It is their privilege to decompose the carbonic acid contained in air and to liberate its elements; that is, oxygen which is exhaled and carbon which is retained in their tissues. And the cultivated area of France—some 41,000,000 hectares—absorbs by this means some 60,000,000 tons of carbon each year. This important operation can, however, be performed only under three conditions. As only green parts are capable of taking carbon from the air, the plant must be provided with chlorophyll—that green substance, which is the cause of the color of leaves, and must be exposed to the rays of the sun and to a favorable temperature. Chlorophyll can decompose carbonic acid only under the influence of light and moderate heat; in darkness and under too great or too low heat it no longer acts, and the result is that plants suffer and die, victims of inanition. For it must be clearly understood that the chlorophyllian function is one of nutrition, quite distinct from the respiratory function. In the latter function plants, like animals, absorb oxygen and exhale carbonic acid; in the former the reverse obtains. The one goes on during night and day, the other is in operation by daytime only, and the function of nutrition lasting less time must necessarily be more active than the respiratory process; otherwise the equilibrium would be destroyed and the plant would lose more than it acquires and consequently suffer.

It is by the leaves mainly, and by the roots in a lesser degree, that atmospheric carbon dioxide is absorbed; but in both cases the gas must be brought to the leaves, to the parts containing chlorophyll, because these parts only can use it—can take the carbon and expel the oxygen.

Hence it follows that this violent poison, this gas which is harmful for all organisms, and which kills them as soon as it accumulates in the atmosphere even in small proportions, is essential to all terrestrial life. If it were to be destroyed, if air were to contain no more of it, all plants on the surface of the earth would die within a short period—some weeks at most. After this, as a matter of course, herbivorous animals would die, and this would not require more than a month. Carnivorous animals would hold out a little longer, as the stronger would feed upon the weak, but after a few weeks they also would go in turn, and only a few miserable, half-starved specimens of mankind would be seen feebly struggling from one rotting carcass to another, amidst as barren scenery as can be observed by looking at the moon through a telescope, and they, too, would have to die soon after, notwithstanding cannibalism or such other extreme methods which dire necessity might suggest. In a few months all nature would be dead.

While carbonic acid is a poison, a substance which endangers life

greatly, it is also a necessity for life, and in the proportions in which it exists in the atmosphere it is just as much a necessity as it would become a fatal danger if it were to be present in larger quantity.

Such are the relations between air considered from the chemical standpoint and life as it exists on earth; between air in its normal, unvitiated, average constitution and life as it manifests itself under the present circumstances.

IV.—Biological Influence of the Atmosphere Considered from the Physical Point of View.

We must now discuss another side of this complex question, we must deal with air considered as a physical substance, and especially as a substance having weight which presses upon all living organisms. This point of view is not less important than the preceding, and deserves some attention, by reason of the relations which exist between life and atmospheric pressure.

The atmosphere, as previously noticed, being a physical substance, possesses weight, and exerts a pressure upon the earth and all beings that inhabit it.[1]

As long as men or animals keep near sea level, or do not climb to exceedingly high altitudes, the normal average variations of pressure, as indicated by the barometer, are of small influence, and the much more considerable variations which are encountered when one ascends mountains or goes up in a balloon are not harmful as long as they do

[1]The average pressure of the atmosphere varies, as before stated, according to the altitude of the locality, and also in the same locality at different times. At the sea level this average pressure amounts to a little over a kilogram per square centimeter, hence the total weight supported by an average man is about 18,000 kilograms. At Mexico the average weight per square centimeter goes down to 793 grams; at Quito, to 752; at Antisana, to 639; and it is no difficult matter to obtain the figure which represents the weight supported by man in such localities, when one knows that the skin surface of an average adult is somewhere between 1,400 and 1,500 square centimeters. The physicist Haüy, explaining and commenting upon the calculations by means of which the average pressure exerted upon the body is ascertained, remarks: "And that is the weight which those philosophers of old had to bear and resist who denied weight to the atmosphere."

This weight or pressure is considerable, but we do not feel it, as all the interior parts of our body exert the same pressure and therefore resist successfully that from the outside. It does not crush us any more than it crushes the soap bubbles, however thin they may be, because in both cases the resistance of internal air or tissues exactly counteracts that of external air. There are very few places in the body where the pressure from within outward does not exactly counteract the opposite pressure, in order to leave all movements perfectly free. Two exceptions, however, must be referred to—that of the pleuræ, between which no counter pressure exists, so that they are compelled by atmospheric pressure to keep strictly in contact, and that of certain articulations, where the head of a bone so exactly fits into a corresponding cavity that there is place for no air between, with the result that the atmospheric pressure forces the former into the latter and keeps it there with sufficient force to resist the counteracting weight of the limb.

not exceed certain limits. But beyond these limits danger exists for both animals and man, and while the effects are not exactly the same for all species, and do not occur at exactly the same altitude with all species, or even individuals of the same species, the general fact remains that at high altitudes, or under very low pressures, life is more or less endangered from different causes. In order to ascertain these causes it is not convenient to take men or animals into high altitudes, as the experimenter would be apt to be also influenced by the diminution of pressure, in consequence of which the value of his observations might be considerably reduced. A better method, easily available, is that used in laboratories, of providing large or small air-proof chambers in which the pressure may be increased or diminished at will, so that, without going out of the laboratory, the same patient or animal may be subjected by turn to the pressure which reigns at the bottom of the deepest mine, or even to far higher pressure, amounting to 800 or 1,000 atmospheres, and to that met on the top of the highest peak of the Himalayas, or at twice or three times that height in the lightest of balloons. With such instruments observation becomes easy, and is effected under the most favorable circumstances, as the operator is able to obtain at a few moments' notice exactly the amount of pressure he wishes to have.

The influence of those extreme pressures, high or low, where life becomes endangered, was very fully investigated by Jourdanet, and afterwards by Paul Bert, and those investigations have taught us by what means they become dangerous. The limits of pressure within which no harm occurs are variable according to species. All terrestrial and aquatic animals may and do resist certain variations in pressure, whether above or below the average. Man, for instance, can work at a kilometer below the sea level without any injury, and he can travel to the height of 5 or 6 kilometers in the atmosphere without being necessarily affected by the decrease of pressure. It is the same with birds and mammals, and surface or shore fishes may go pretty deep in the seas without experiencing any unpleasant effects, while deep-sea fish may travel upward for some time before reaching the danger line, so to speak. But for all organisms there are limits in the variation of pressure which can not be transgressed with impunity; there are limits beyond which life is destroyed.

How is death induced in such cases? We must consider the two different cases in turn, and shall begin with the effects of diminished pressure.

Four hundred years have now elapsed since a Jesuit missionary, Acosta, left us an excellent description of the accidents which attend ascensions in high mountains, or important diminution of pressure. "While ascending a mountain in Peru," writes Acosta, "I was suddenly affected by so strange and so mortal an evil that I nearly dropped from my horse to the ground. * * * I was alone with an Indian, and

asked him to help me to keep on my animal, and I was taken with such pain, sobbing, and vomiting, that I thought I should die, and, moreover after having vomited food, phlegm (mucous matter), and bile, yellow first and afterwards green. I even threw up blood, such pains had I in my stomach; and I am sure that if it had lasted longer I would certainly have died. As it was it lasted only three or four hours, till we had reached a much lower region. And not only men, but animals also were affected." And further on, "I feel confident that the substance of the air in such places is so subtle and thin that it is unsuitable for human respiration, which requires it thicker and better adapted." This was written three hundred years before the time of Priestley and Lavoisier, and yet the expressions used by Acosta are really most happy. Atmospheric air in the altitudes is too thin, too rarefied, too subtle for the respiration of superior organisms. The evil described by Acosta is that which, in different countries and places, is named *puña*, *soroche*, *veta*, *mal des montagnes*, *mountain sickness*, *balloon sickness*. It has been more recently and fully described and investigated by Tschudi, Lortet, and many others; each has noticed the vertigo, vomiting, anxiety, and fainting which characterize it; and exact experiments—those of Lortet and Chauveau, among others—have shown that respiration is diminished and at the same time accelerated; intense muscular pains have been noticed, and also circulatory and nervous symptoms, which end in paralysis and death if the perturbations continue, as in case of the *Zenith* catastrophe.

While it would be quite superfluous for our present purpose to review the opinions which have at different times been entertained concerning the cause of these dangerous perturbations, we may briefly summarize the explanation thereof recently given by Paul Bert and others.

This is quite simple. The symptoms and death are due to a diminution in the tension of oxygen, which is itself due to the rarefaction of that gas. As everyone will understand, if the same volume contains in high altitudes less weight of air than in low altitudes or at the sea level, it follows that in the former condition there is less air available, less of each constituent, less oxygen. In the heights of the atmosphere air is made up of the same elements as below, but they are less in quantity although the proportions are the same; air is dilated, rarened, thinner, less dense, and of the essential element—oxygen—a smaller quantity is inhaled at each respiratory movement, although the volume of inspired air is the same. Under such circumstances, as Paul Bert's investigations go to show, decrease of pressure kills, not mechanically, but by a chemical process. High altitudes kill because they induce a state of anoxyhæmia, a state in which the blood is deficient in oxygen. The animal—or man—in rarefied air, dies for the same reason that one dies in a confined atmosphere; in both cases there is an insufficiency of oxygen.

Another cause also operates, in the case of fishes or other aquatic animals that live at great depths, when they happen to rise too near the surface, thus coming from high to low pressure. The gases of the body, dissolved in the liquids (blood, etc.), have a higher tension than the outside pressure, and the result is that these gases expand and burst the tissues within which they are contained when the exterior pressure becomes less than that which reigns in the interior. The case is exactly that of a bladder inflated with air placed in the receiver of an air pump; if the air of the cylinder is gradually exhausted, the bladder swells until it explodes. This is an extreme case, which hardly occurs under natural conditions, but other accidents of a similar nature, which are explained by the same mechanism, often do occur in man or animals, as we shall show further on.

We can not leave this subject without adding a few words concerning mountain sickness. It is a well-known fact that at the same altitude different aeronauts or tourists are not equally affected. Of course this statement refers only to moderate altitudes, between 3,000 and 4,000 meters. At the very same place, on the same day, one person is a victim to mountain sickness and another is not. As only individuals of the same species are compared, the reason of the difference can only lie in personal or individual peculiarities; no specific physiological differences can exist such as those met with when one compares the influence of one and the same agency or poison, etc., upon individuals of different species; there is no evident and tangible cause such as that which one detects when comparing the resistance of the duck and of the common fowl to submersion, when the greater resistance of the former is due to its greater amount of blood, and consequently more considerable provision of oxygen. There are doubtless physiological differences of real importance between different individuals belonging to the same species, and between different varieties of the same species; considered *in toto* those differences are more important and more frequent than commonly supposed, and probably more important than those external morphological characters which are the bases of classification at present. But such important differences can not obtain between two individuals belonging to the same species, and the fact that they may occur one day and be wanting a week later, shows that they are merely accidental and temporary.

Mountain sickness is due to a condition of asphyxia, as already noticed, and this fact explains the differences referred to, as an ingenious experiment performed by M. Paul Regnard amply shows. This experiment was suggested by the proposal, made by a company, to build a lift by which to reach the top of the Jungfrau, the well-known Alpine peak. Before setting to work, it was desirable to ascertain whether the passage from low to high altitude would not produce unpleasant symptoms in the tourists using the lift,[1] and to show that

[1] The lift was to be established in vertical shafts from a horizontal tunnel at the base of the mountain to the top.

under the circumstances attending the excursion, mountain sickness was not to be feared. M. Regnard's experiment answers this question. As far as physiologists are concerned, the question was settled, but the general public required to be satisfied upon this point. The experiment is easily repeated in any laboratory, and it is quite unnecessary to ascend Mont Blanc or the Himalayas for the purpose. All that is required is a glass bell jar, an exhausting pump, and a pair of guinea pigs. The bell jar must be rather wide, and it is placed—inverted—upon a smooth and even surface, such as that which can be afforded by a thick pane of glass.

The edge of the jar is smeared with tallow, so that when placed upon the pane the access of air is entirely prevented. Under it are the two guinea pigs. One is free and does as he chooses; the other is placed in a small treadmill where he is compelled to exert himself somewhat in order to preserve his equilibrium, as the treadmill is made to turn round by means of electricity. The two animals represent, the first, an aeronaut, or a person quietly sitting in a lift where no exertion is required; the other, a mountain climber, who has to expend energy, and to work if he wants to get to the top; and now both must be placed in a condition similar to those which obtain in high altitudes. A few strokes of the air pump connected with the bell are enough to bring the pressure to correspond exactly with that which exists at 2,000, at 3,000, at 4,000 meters height, and a manometer shows the pressure produced. So this experiment begins, and the atmosphere within the bell is slowly rarefied, as would happen in the case of a slowly ascending lift or mountain climber, and because, also, rapid decrease of pressure would be most dangerous. Up to the decrease of pressure which corresponds to a 3,000 meters altitude both animals remain quite well, the one who works his way up, so to say, as well as the other who keeps quiet or only walks a few paces to the right or left. The process is continued and the rarefaction increased. Before the pressure corresponding to 4,000 meters altitude is attained, however, the "working" guinea pig manifests evidence of physiological discontent. Now and then he stumbles, and does not exactly keep pace with the treadmill; he even rolls over and is clearly out of breath. When the manometer shows the pressure to be that which corresponds to a 4,600 meters altitude (210 meters less than the altitude of Mont Blanc), this guinea pig is entirely disabled. He can walk no more; rolls on his back, and is rolled by the treadmill; he moves no longer. In fact, he seems quite dead. Life is not extinct, though, and the animal moves when air is again let into the jar. The other animal is in an excellent state of health. At no moment has he presented the slightest symptoms; he nibbles at cabbage, and seems quite unconcerned with the experiment. It does not affect him in the least.

It may then be considered as settled that the quantity and quality of the air contained in the jar are quite sufficient; that they are adequate

to maintain life. And if one of the guinea pigs exhibits symptoms of asphyxia, these are not ascribable to the nature of the atmosphere. If the experiment is pursued and air further rarefied, it is not until the decrease of pressure corresponds to that which obtains at the top of some peaks of the Himalayas (8,000 meters, the altitude attained by Glaisher, but in a state of unconsciousness) that the hitherto unaffected guinea pig shows symptoms of asphyxia. Such symptoms were certain to occur, since the quantity of air was decreasing all the time and must at some moment become insufficient. And now the experiment has proceeded far enough, as there is no necessity at all for killing the animals, and death must surely be the result if the experiment is allowed to continue; air is now let in slowly. Both animals recover entirely, the latter in shorter time than the former.

Now, what does the experiment show? It shows that in itself altitude or the decrease of pressure corresponding to altitude within the limits of 3,000, 4,000, 5,000 meters or even more (under 8,000 meters) is not sufficient to induce asphyxia and the symptoms of mountain sickness. The proof thereof lies in the fact that the inactive guinea pig exhibited no asphyxic symptoms at such altitudes. At 8,000 meters these made their appearance. They were unavoidable. They might have begun a little earlier, they might begin a little later—that is, at rather lower or rather higher pressure—according to the species and individual; but it is certain that for all organisms there is a limit in the heights of the atmosphere above which air is too rare and tenuous to maintain life, and asphyxia must ensue. This first fact, however, was already known, and M. P. Regnard's experiment proves nothing new in that line. What it shows is that muscular effort hastens the production of asphyxia or mountain sickness, and of this the active guinea pig provides an excellent demonstration. Now, muscular effort hastens asphyxia or mountain sickness because it is itself a cause of relative asphyxia. The organism that works and expends energy uses more oxygen, and therefore needs more than that which keeps quiet. The panting which follows running, or is the consequence of rapid muscular work with the arms, legs, or whole body, of violent exercise, proves that the body requires more oxygen, and if the expired gases are analyzed it is shown that carbonic acid exhalation is increased, and it is clear, therefore, that more oxygen is required, since the oxygen contained in carbonic acid is borrowed from the inhaled air.

M. P. Regnard's guinea pigs are exact representations, the one of the aeronaut or of the person in the lift, the other of the Alpine climber; and since muscular exertion alone induces a state of incipient asphyxia it is to be expected that in rarefied air, which itself tends to the same end, that condition should occur quicker in the organism which by its activity goes, as one may say, to meet it.

Practical conclusions are easily drawn from this demonstration. There is no reason for the persons who may be carried up the Jungfrau in the

projected lift to fear the effects of altitude. The example of the inactive guinea pig assures them of immunity, and except in some almost impossible cases of anæmia or weakness they will experience no discomfort. On the other hand, incipient alpinists must perceive that the advice commonly given by guides has a solid foundation. The example of the active guinea pig shows them that ascensions must be performed slowly, without haste, without great exertion, without getting out of breath. To be out of breath means incipient asphyxia, and asphyxia means mountain sickness. So the excursionist must learn to climb slowly, with careful and measured step.

In brief, high altitudes must unavoidably bring on asphyxia and mountain sickness, but at moderate altitudes both are avoidable by reducing the exertion; they may be brought on by increasing one's efforts, and it is only by assuming the nearly perfect immobility of the aeronaut that one can hope to attain without discomfort the highest altitudes, since it is during such immobility that the organism needs least air.

Having considered the case where an animal or man passes gradually from a low to a high level, we must now turn to another, that in which the change is sudden or extremely rapid. This is not exceptional, but does not occur in the course of mountain climbing, for obvious reasons; and in the case of balloon ascents, where it would seem to be of common occurrence, we rarely hear of any serious inconvenience experienced, although the balloon often seems to rise very rapidly. The truth is that it rises rapidly to a moderate altitude only, and that it gets into really high altitudes only after a lapse of time quite sufficient for adaptation. To encounter cases of rapid decrease of pressure, we must turn in another direction, and we find examples where men work under high pressure, for instance, in diving bells, under the surface of the sea or of a river, to explore a wreck or build the foundations of a pier or bridge. Here, in order to counteract the great pressure overhead, that of the water added to the normal sea-level pressure—and every ten meters in depth of water adds the pressure of one atmosphere—air must be forced into the bell or diving apparatus, and the men are subjected to a total pressure amounting to three or four atmospheres. As it sometimes accidentally happens that the passage from this high pressure to the normal air is very rapid, the study of the results is instructive for the present purpose. These are often most unfavorable and death not uncommonly ensues. The same occurs when an animal in a bell jar is rapidly subjected to a decrease of pressure, or when, in a bell jar, where an animal has been placed and the pressure gradually increased by forcing air into it, the pressure is suddenly decreased merely by allowing the air to escape into the atmosphere. In both cases, and in fact in all cases where the passage from relatively high to comparatively low pressure is rapid or quite sudden, symptoms arise which are generally fatal. The animal falls on its side

and dies, even if the final pressure is one which, if brought on slowly, would not be injurious to life. The danger lies only in the rapidity of the change.

Post-mortem examination of the victim affords a clue to the cause of death, and makes all symptoms clear and intelligible. We find gas or air in free condition under the skin, in the tissues, in the blood vessels; this we never observe under normal conditions. These gases are the cause of death. All tissues, and the blood, of course, contain at all times gaseous matters—oxygen, nitrogen, carbonic acid—either dissolved in the liquids or combined with hemoglobin in the blood, and the amount of these gases varies according to external pressure, according to the tension of atmosphere. Now, if the atmospheric pressure decreases gradually, the tension of the gases of the organism decreases accordingly; and they escape gradually into the atmosphere without making any trouble. But if the decrease is sudden, this gradual escape can not be effected; the liberated gases have no time to escape; the result is that they accumulate in all parts of the body, and in the circulatory system they obstruct small vessels and paralyze the heart.[1] Such accidents are not uncommon among the workmen referred to, and this is the reason why they are always advised to come up slowly to the surface, and the deeper they have been the slower the change should be. They have little to fear from working in compressed air at 2, 3, or 4 atmospheres; the danger lies in the decrease of pressure, which, if sudden, is generally fatal. As they say in their own language, "You have to pay only when you come out."

So much for decrease of pressure, rapid or slow. In the one case it injures by a deficiency of oxygen, by anoxyhæmia, and the only way to counteract its effects is to be provided with a supply of oxygen of which small amounts may be inhaled now and then. Aeronauts intending to attain very high altitudes can not do without such a provision, and it is their custom now to always take with them a supply of oxygen. In the other, the injury is the result of a quite different process, purely mechanical, the sudden liberation of gases in the tissues and especially in the blood, where they immediately interfere with the circulation, and stop the heart's action. When moderate pressure suddenly follows high pressure, anoxyhæmia plays no part, and only the mechanical effects occur; if low pressure follows moderate and sufficient pressure, anoxyhæmia alone occurs if the passage is slow; anoxyhæmia and the mechanical liberation of gases ensue if the passage is rapid and sudden. In both cases, decrease of pressure interferes with life.

Let us now consider the reverse case, that of an increase of pressure. Under normal circumstances such increase is always unimportant.

[1] Just as air, even in very small quantity, drawn in the circulatory system through some lesion of the venous system near the heart induces death in a few seconds, as all physiologists know.

Even at the bottom of the deepest mines, although pressure is appreciably increased, this increase can not be considered as exerting the slightest evil influence, and its physiological effects are practically nil. The increase of pressure is much more important in the case of diving bells, and it is among workmen who are engaged in the building of piers and wharves, or in the exploration of wrecks, that we must search for information concerning the effects of high atmospheric pressure, unless we turn to animals experimentally subjected to such condition in bell jars connected with forcing pumps. When the increase is slight, the effects are also slight. Some buzzing in the ears, some bleeding at the nose, and a slight numbness in the limbs are those which are most appreciable. But, at the same time, the respiration and circulation are slower. In some cases there occurs an abnormal excitation of the nervous system similar to that observed during acute alcoholism. Such accidents are quite naturally ascribed to an increase in the tension of carbonic acid, which accumulates in the system and determines incipient asphyxia. This interpretation is correct as long as the increase of pressure is moderate. But when the increase of pressure is considerable, when we have to deal with pressure of six or more atmospheres, the case is altered, and the cause of the symptoms is different. This is shown by Paul Bert's various experiments. In order to delay the effects of increase of pressure, he added pure oxygen to the atmosphere inspired by the animals experimented upon, expecting by this means to prevent the toxic influence of carbonic acid. He was, therefore, considerably surprised when he perceived that this had no other result than to hasten the fatal issue. He then proceeded to a careful analysis of the symptoms and phenomena, and perceived that when the pressure is over 6 atmospheres the oxygen contained in the atmosphere, acquiring a high tension, becomes a poison. And none can wonder at this. An increase of the proportion of oxygen under normal pressure is attended by toxic symptoms; an increase in the pressure of oxygen, which amounts to the same thing, must exert the same influence. And the proof that oxygen is the only culprit lies in the fact that an animal can perfectly well endure a pressure of 20 atmospheres if the air is poor in oxygen, if oxygen, being less in quantity, has, in the mixture, a tension which does not exceed that which the normal amount of oxygen, in normal air, possesses under normal pressure. Under increased tension, as well as in increased proportion—for both conditions are identical as far as physiology is concerned—oxygen is a poison, and a very dangerous one, and this is the reason why man and animals die in a normal atmosphere, when the pressure exceeds certain limits. Be it rapid or slow, considerable increase of pressure kills through the agency of oxygen and of its toxic properties, by reason of oxygen being dissolved in the blood serum. If we leave out of consideration those cases where the variations of pressure are rapid, and where, as is the case with rapid decrease

of pressure, a purely mechanical element comes into play, one sees that gradual variations operate, not physically nor mechanically, but in a purely chemical manner, by putting the organism under the influence of an atmosphere too rich or too poor in oxygen.

It must be added that in this case, as well as in many others, adaptive phenomena occur. The Indians and animals of the South American Cordilleras are unaffected by mountain sickness which attacks the unaccustomed traveler, and animals of the abysses of the sea live and thrive under pressures which no terrestrial or shore animal could endure.

This fact of adaptation to altitude, which is confirmed by the other fact that there are villages or cities permanently inhabited by man at 3,000 and 4,000 meters above sea level, has long been well known. It has especially attracted the attention of a French physiologist, Dr. Jourdanet, who discovered most of the facts which Paul Bert investigated later; but the mechanism of the phenomena has been only recently explained. Jourdanet supposed that the inhabitants of low levels, when transferred to high levels, meeting with low pressure and consequently a small proportion of oxygen, became affected by anoxyhæmia, a state characterized by the inability of the red blood corpuscles to absorb a sufficient proportion of oxygen—in brief, incipient asphyxia.

In that he was right; he also thought that adaptation is effected in the following manner: If the evil is not unbearable, the system begins to produce a larger supply of blood corpuscles; these can absorb only a small proportion of oxygen to be sure, but then they are more numerous, and by this means the balance is restored, and the system may absorb a sufficient quantity of oxygen. Here, again, he was right, but he did not succeed in establishing his hypothesis on a firm basis. The latter task was achieved by Paul Bert, who examined specimens of the blood of Peruvian llamas and vicuñas, and proved that the blood of such of these animals as live on the highlands contains a larger proportion of hæmoglobin and of oxygen than that of those of the same species living on the plains at lower levels. For instance, 100 cubic centimeters of blood of llamas or vicuñas living on the highlands contain between 19 and 21 cubic centimeters of oxygen, while the same amount of blood in animals of the same species living on the lowlands contains only 12 to 15 cubic centimeters.

These results have been very positively confirmed by the investigations of MM. Viault, Maron, and Regnard. M. Müntz has shown that in common domestic rabbits allowed to go wild upon the heights of the Pic du Midi, in France, the blood, after ten months' sojourn in the mountains, contains much more hæmoglobin than that of rabbits belonging to the same breeds released for the same length of time in the plains at Bagnères de Bigorre. But it may be objected that this experiment is not as conclusive as it seems to be, owing to the fact that the rabbits of the Pic du Midi may have been surrounded there by different

environmental conditions other than those of altitude which may have produced the observed effects. In order to meet this argument M. Paul Regnard has devised an experiment which affords a very precise and unassailable demonstration. In this experiment the only difference is a difference in pressure. If the increase in the respiratory capacity of the blood that occurs in consequence of life at high altitudes is occasioned solely by diminution of pressure, it is clear that such diminution ought to produce the same effect at any altitude whatever. So M. Paul Regnard took two guinea pigs belonging to the same litter, placed one in a bell jar, where a special apparatus not only provided the necessary decrease of pressure (by exhausting the atmosphere to the requisite degree), but effected the necessary ventilation, while the other lived in the same laboratory under normal pressure. The decrease of pressure in the bell jar and the density of the atmosphere corresponded exactly to those which obtain at Santa Fe de Bogota, at 3,000 meters above sea level. Both animals were killed after a month, and the result was that the blood of the guinea pig under decreased pressure absorbed 21 cubic centimeters of oxygen (per 100 cubic centimeters blood), while that of the other animal living under normal pressure absorbed only 14 to 15 cubic centimeters of oxygen at the most. The fact is quite clear; the experiment most convincing. By some means not yet ascertained the blood of creatures living at high altitudes, and able to withstand the first unpleasant sensations, acquires the power of accumulating a large proportion of oxygen, and thus their systems are enabled to resist that incipient asphyxia which is the result of a smaller proportion of oxygen in the atmosphere.

This is an important point, from the practical side. It explains the beneficent influence of high-level stations (such as St. Moriz, in Switzerland) upon anæmic or tuberculous patients. It shows that in cases where the organism is weakened and physiologically impoverished, and particularly where the blood has lost some of its vitality, the patient will be benefited by living for some time in mountain resorts, even at comparatively high altitudes, his blood will acquire new life, and become more apt to fulfill its functions, owing to the increase of respiratory capacity that results from decrease of pressure.

It is evident, however, that the patient should begin with moderate altitudes, 1,500 meters, for instance; with altitudes which do not overtask the system, which do not palpably increase the physiological tendency toward asphyxia, and one should not forget that decrease of pressure which, if moderate, is beneficent, becomes invariably fatal if it exceeds certain limits. Man does not seem to be adapted to live permanently at altitudes over 4,000 or 5,000 meters, and if other animals are able to do so, it is quite certain that even for these also there is a limit upon which they can not trespass without dangerous results. The differences are only of degree, and upon the whole they are of small amount.

MOVEMENTS OF THE ATMOSPHERE.

We must now consider another side of the general topic of the physics of air. I refer to the movements which unceasingly occur in the vast ocean of gas which surrounds our planet. They are familiar to all. It is these that swell the sails of vessels and carry them across the oceans, that give the impulse to the old-fashioned windmill, that lift the waves and send them rolling from continent to continent; these, also, that, with cyclones and tornadoes, uproot trees, blow down houses, destroy crops, snap the giants of the forests like mere twigs, raise clouds of dust, and spread ruin and death on every side. Breeze or tempest, it always is air in motion, and in this case as well as in others air is both beneficent and maleficent. Concerning the cause of this motion, be it gentle or be it violent, it is enough to remind the reader that the main if not exclusive cause is in difference of calefaction, and that the wind blows from cool areas to warm ones.

What part can these movements of the atmosphere play in the life of our planet? What is their influence? A superficial glance is enough to show that this is manifold.

In the first place, they help to intermingle the constituents of the atmosphere. To be sure, the general constitution of air is the same everywhere, no considerable difference existing. But we have referred more than once to the numerous local causes of alteration. Consider, for instance, a large industrial town or a volcano. Both exhale an enormous amount of obnoxious gases which are poured into the atmosphere—carbon dioxide, carbon monoxide, and a hundred other substances, toxic or inert; at all events undesirable for breathing. A few figures have been given above concerning the amount of such gases produced by mankind, by combustion, etc., and we all know that in cities the composition of air is less pure than in the country; that Manchester, Birmingham, Chicago, Pittsburgh, etc., are less healthy than their surroundings. If there were no winds, most certainly things would be much worse than they are, and, the very fact that city air is inferior to country air, substantiates this assertion. Without winds all these gases would accumulate about the place where they originated. Of course some diffusion would take place, but the process would be a slow one, and a much too great proportion of unhealthy gases would at all times be found in the air of such places, which would thus be more insalubrious than they now are. Without winds locally vitiated air would remain such, just as is the case with the atmosphere in a closed room where men or animals are assembled; wind is the cleanser of the atmosphere, the great purifier, which mixes and purifies it, which chases it over lands and seas, over fields and forests, from pole to equator, and from equator to pole, thus dissipating in the whole mass those elements which, for one reason or another, are produced in greater abundance at some points; it maintains the purity

of the atmosphere, or at least its homogeneity. If the atmosphere were motionless, the air in cities would be perpetually vitiated, and all the carbonic acid which originates there would be delayed in its travel toward the country, the fields, and the forests, in whose biology it plays so important a part: the vicinity of volcanoes, and even of cities, would be uninhabitable, and life in cities impossible.

Again, from a biological standpoint, the movements of the atmosphere are useful in another way. They prevent the air from remaining excessively dry in some regions and inordinately damp in others. The air which has accumulated a large amount of humidity while above an ocean, a lake, a river, a forest, does not remain there. It travels farther, and carries the aqueous vapor it contains inland, up mountains, and over plains. It transports the clouds, and carries the water drawn from the Pacific Ocean to fall in rain on the American continent: through the same agency the water drawn from the Atlantic falls on Europe, and the water of oceans is carried through the atmosphere to enormous distances to provide the continents with the rain essential to plants, animals, and man, both that immediately used and that which, sinking through the soil, comes to light again, sometimes at considerable distances, under the form of springs, which help to make the streams and rivers. If winds did not occur as they do, if the aerial ocean were motionless, the vapors which arise above the oceans and masses of water would not travel so fast, so far, nor in such quantity, and a great part of our globe would be condemned to drought and sterility. The other part would hardly be pleasanter; in an atmosphere saturated with vapor, as that would be, perspiration evaporates most slowly, and if the temperature were even moderately high, man would lead a sluggish life, shunning effort as inducing an uncomfortable condition, and living in a laziness and *far niente* which have never conduced to moral, mental, or physical advancement. Truly wind is no unimportant agency in civilization and in the general evolution of mankind.

Again, the movements of the atmosphere play an important part in the regulation of temperature, as they do in the regulation of humidity. If they did not occur, air would be perpetually warm in some places and perpetually cold in others, the radiation and diffusion of heat acting but slowly. The wind is beneficent in that it carries warm air to cold regions and cold air to warm ones, tempering the climate of each.

To end this chapter, a word must be said of the part which wind plays in the biology of many species of plants, by providing them with important means of dispersion. Many plants possess light seeds, which are, moreover, provided with appendages in the form of wings, or of feathery hairs, and such seeds are very easily carried to considerable distances over plains, over rivers, and even over narrow sea channels. Through the wind's agency, these species are transported to new habitats, where they may settle and thrive, spreading gradually over large tracts. Numbers of insects and birds are thus carried to great distances

by storms, and are thus enabled to obtain a foothold upon islands or continents to which their own forces could not have brought them. And micro-organisms, last but by no means least, as far as importance, not size, is concerned, make great use of atmospheric movements. They possess no means of locomotion, and have no limbs to carry them to a distance; but the wind makes good this deficiency, and takes good care to scatter them far and wide. There are many epidemics propagated from city to city, from country to country; there are death-working as well as beneficent microbes scattered over the whole face of the earth, and thus air is again an agent of death and of life by its contents, no less than by its essential constituents. But air contains also a large proportion of non-living matter, of dead dust as contrasted with the living dust just referred to. Such dust also is scattered far and wide, and there is no doubt but that it may be carried from China to North America, and from the New World to Europe or Africa. This dispersal of dust may be of some importance in agriculture; at all events it plays no insignificant part in geology, and all have heard of the influence of winds in the formation and migration of dunes on the seacoasts. This influence is often important. In France, in the region at the south of Bordeaux and in certain parts of Brittany, the wind has brought so much sand from the dry shores at low tide that man has been compelled to retreat and to desert his villages. These, gradually covered by the particles carried by the winds, have finally been entirely engulfed and buried, as were Herculaneum and Pompeii of old under the cinders of Vesuvius, and the only remnant of a once inhabited and prosperous hamlet is a spire which sticks out of the plain of sand. Analogous phenomena are to be observed in all countries. In 1889, according to Mr. George P. Merrill, a storm occurred in Dakota during which the soil was torn up to the depth of 4 or 5 inches, and the particles accumulated easily in recognizable sand dunes. In the western plains of North America, also, the same event occurs, and these dunes, when once formed, travel and migrate from place to place. Some miles north of Lake Winnemucca (Nevada), Mr. Russell found a series of such dunes, 40 miles long, 8 miles wide, some of which were 75 feet high. Near Alkali Lake other dunes are 200 and 300 feet high, and on the eastern shore of Lake Michigan similar dunes have advanced upon forests, which they have invaded, smothered, and destroyed, and the tops only of the trees, dead as a matter of course, emerge above the hillocks of sand.

It should be observed that particles of sand driven by the wind exert an erosive influence. They act as files, and gradually wear away the rocks which they unceasingly batter, and thus the wind works in two ways toward the leveling of the globe; indirectly cooperating with water and with frost it helps to disintegrate the elements of rocks; and when they are broken down it carries the particles, which are the ultimate result of such disintegration, to the plains and to the sea.

If one observes that besides this work wind is capable of tremendous effort; that it wrenches from the soil the strongest trees; that it scatters to the ground in crumbling ruins the most solid monuments or buildings; if one considers that it could also effect a much greater amount of work than that which is at present effected, by driving sailing vessels or windmills, one can not forego the conclusion that in wind we have an enormous source of energy which is hardly utilized from the industrial point of view.

This is undoubtedly true. Wind is a most powerful force, whose limits can not possibly be estimated: that it could be utilized for man's benefit could hardly fail to suggest itself. Many centuries have passed since the first endeavor, and although some progress has been made, and has been satisfactory enough during a long period, no one will venture to assert that nothing more can be done.

Wind has been used on land and on sea; windmills have been invented in most lands, and few savage tribes have failed to become aware of the great help sails are to navigation. For centuries civilized nations were content with sailing vessels, and some of the latter were truly splendid achievements, able, it must be remembered, to cross the Atlantic—under favorable circumstances—in eleven days, which is still the duration of the trip for average steamships. But for three-quarters of a century steam has been used and defeated sails for long distances. The best steamers of the transatlantic lines are able to run from Queenstown to New York in five days and a half, and from New York to Havre in six days and a fraction. Wind has been defeated by steam on land also, and coal has taken the first place as a source of energy. But coal supplies are not inexhaustible, and thoughtful minds are concerned with the important problem of drawing upon those other resources which the movements of the atmosphere still provide, and which are by no means used as much as they might be. Coal is decreasing, and no fresh strata of the precious store are in process of formation as far as we are aware. It is burned at the rate of millions of tons each year, and mines are being steadily emptied of their contents. Forethought demands that future generations be not caught unawares, and that even now the problem of providing fresh sources of energy be considered. These are not wanting. The application of electricity to general uses has developed important possibilities, and provided us with a method by means of which energy may be obtained, transformed and carried to a distance with the result that with proper apparatus the energy of rivers, of winds, of tides, of solar heat, may be utilized. Some important steps have been made in the required direction, and much has been done to utilize the energy contained in rivers under the form of falls, in Europe as well as in the United States, where the Niagara Falls are the best known instance. But concerning the power contained in wind, little has been done to take advantage of it. Sailing vessels are always numerous, to be sure, but windmills are, on the

contrary, on the decrease, and no new method has been devised of late to increase the quantity of force derived from this source. M. Maximilian Plessner, however, has done good work in trying to call public attention to the matter.[1] Wind is doubtless very irregular, by turns strong or even violent, and a short time afterwards very gentle, and even ceasing. But a great deal depends upon localities. There are places and large regions where the wind is quite regular enough, as far as strength and constancy are concerned, and near the seashore it seldom fails. In the subtropical regions, also, trade winds are very constant, and in most parts of the globe the regularity of the wind increases with the altitude. The latter fact has been well shown by a continuous series of observations made at the Eiffel Tower, in Paris, since 1889. This amounts to asserting that, upon the whole, a considerable part of the globe is perfectly suited for investigations upon the best methods of deriving power from the winds. M. Plessner has calculated that a wall or curtain 1,000 meters high placed upon the fifty-fourth parallel between the twenty-fourth and thirty-eighth degrees of longitude, would receive, through the impact of the wind, a total sum of 100,000,000 horsepower, and 130 such walls would provide 13,000,000,000 horsepower, which means the power of 1,000 Niagaras. Of course no such apparatus could be erected and used, as the first storm would destroy the whole fabric; but this helps us to realize the tremendous amount of energy which speeds over our heads. The first requisite is some sort of motor driven by the wind, and an accumulator to store the energy and yield it at the required moment. M. Plessner has no admiration for the old windmill; he does not find therein the motor which engrosses his thoughts or dreams. The æolian wheel would be more suitable, but this also is below his requirements, and he is rather inclined to look upon sails as affording a possible solution of the problem. "The utilization of the power of winds," he writes, "and its transformation into mechanical work, are possible only by means of sailing vehicles, driven by wind upon a circular railway, the power generated by such rotation being transmitted to an axle, and thence to machinery." He therefore proposes a circular railway, at ground level, or, better still, elevated upon trestles. On this railway a circular or annular train, made of small cars coupled together, each carrying a mast and two sails at right angles with each other, is driven by the wind. These sails are automatically trimmed, and automatically, also, they expand or contract, or rather take in the wind or withdraw from it. As long as the wind blows, the train continues rotating, and if it is connected with a central axle, the latter may work dynamos and charge electric accumulators. A similar apparatus might be arranged in water, boats taking the place of the cars, and since the wind power

[1] See his book: Ein Blick auf die grossen Erfindungen des zwanzigsten Jahrhunderts—Die Dienstbarmachung der Windkraft für den elektrischen Motoren-Betrieb, Berlin, 1893.

is transformed into electricity the latter may be stored and kept in reserve, or transferred to a distance to perform 10, 20, 50 miles away any work that may be required.

Such is, in its main features, M. Plessner's project. Whether it be this or some other which is accepted, there is no doubt as to the necessity of trying to utilize a small fraction of the tremendous energy that produces the movements of the atmosphere, and is one of the results of the action of solar heat on our planet. There are certainly many ways in which the problem may be solved. For instance, a very simple method would be the using of wind power to force water into a reservoir at some height from which it might, at will, be let out to work turbines. In mountainous regions, and near the sea, in all places where water and wind are available, this system might be of service, however imperfect it may seem. At all events a great field is open to inventors, and a great harvest may be reaped by those who will work it with patience and skill. M. Plessner's investigations will prove very suggestive, and they may also find much that is useful in Mr. S. P. Langley's memoir on The Internal Work of the Wind. The facts referred to by Professor Langley are perhaps of more importance for the problem of aviation, or flight, and for the explanation of the soaring of the larger birds, which all have oftentimes seen sustaining themselves during whole hours, without apparent fatigue, or effort, but they are certainly very suggestive in the realm of aerodynamics. Mr. S. P. Langley has succeeded in proving that the force of the wind is not by any means as constant and uniform as is commonly supposed. It does not impart an approximately uniform movement, but a succession of short, rapid waves or pulsations of varying intensity, and fluctuating in direction on either side of the general course of the wind. He considers it as certain that an inclined or suitably curved surface, heavier than air, and free from all attachments whatsoever, may be uplifted and indefinitely supported in the air by means of "internal work," without any further expense of energy than that which is demanded for changing the inclinations of the plane according to the pulsations. It seems quite certain that under special conditions such a plane might advance against the wind, not only comparatively, but in the absolute sense. These data are very valuable, and may prove most useful for practical purposes.

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Having considered the general relationship between living organisms and the elements, pressure, and movements of the atmosphere, we must now proceed to illustrate the relationship between the physical contents of the air and living beings.

Air contains many elements that are accidental, temporary, and of minor importance. Some are gases; such as, for instance, carbon monoxide, carbureted hydrogen, and many others, for the most part obnoxious and toxic. Of these substances we shall say nothing here, because of their scarcity and irregular occurrence. They are not normal

constituents of the atmosphere, and we may say that every substance known to chemistry may at some time or place be accidently present in the air. Only such bodies deserve notice as are normally present in the whole atmosphere, although they may be of minor importance. Under this head must be mentioned aqueous vapor and different solid materials, inanimate or animate, excluding those which are of volcanic origin, and dust, natural or artificial.

Aqueous vapor is always present in the atmosphere under the form of fog or clouds, and also in an invisible form. We will especially refer to the latter. It has a dual origin. The one part comes from evaporation, under the influence of heat, of the water of oceans, rivers, lakes, and moist soil. The amount of vapor produced depends upon the amount of heat, and also upon the amount of vapor already contained in the air. For each degree of temperature air can only contain a quite definite amount of vapor. The other part comes from living organisms, by transpiration through the skin and pulmonary surfaces of animals, by the evaporation which occurs from the leaves of plants. This production of aqueous vapor by living beings is very variable, and circumstances affect it greatly. An animal or man in dry air produces a large amount, since the expired air is quite saturated with it, but in moist air hardly any is produced, and that which is expired hardly does more than restore to the atmosphere the moisture taken from it. The whole of mankind pours into the atmosphere a total amount of some 15,000,000,000 kilograms of water per twenty-four hours, but a large proportion of this is merely returned; it has not been generated by man. Similarly, plants yield but a small amount of moisture if the air is already nearly saturated; they yield a very large amount if it is dry. It has been calculated, for example, that a wood of 500 adult and vigorous trees yields nearly 4,000 tons of aqueous vapor during the twelve hours of daylight. By night the amount is less considerable, and is only about one-fifth of the diurnal evaporation. This instance is enough to show that plants are most important producers of vapor. And if one only considers that in the United States, as an example, the total surface of plant leaves is at least four times that of the soil surface, one perceives how important must be the part of plants in the function we refer to. Physicists have estimated the total quantity of aqueous vapor in the atmosphere at 72,000,000,000,000 tons or cubic meters of water.

This vapor, which is very unequally diffused (since the maximum amount depends upon the temperature of air), and which varies in quantity according to the time, locality, and other circumstances, plays an important biological part. Air, when too dry irritates the respiratory organs; when too moist it impedes transpiration and its beneficent effects: *in medio virtus*, and the best condition is that in which air is neither very dry nor very moist.

Another more important part is played by this aqueous vapor in that

it forms a sort of protecting screen, that, by day, tempers the solar heat by absorbing a portion of it and preventing it from scorching the vegetation and the soil, and at night, conversely, prevents excessive cooling of the earth's surface by radiation. It does not prevent the passage of luminous calorific rays, but absorbs a large amount of the dark thermic rays—whatever their source—and experiments by Tyndall, and especially Pouillet, and others, have shown that the atmosphere, by reason of the vapor it contains, absorbs about a quarter of the sun's heat, so that only three-quarters reach the earth proper. If this screen did not exist, our summer days would be much hotter and also much cooler. In the full glare of the sun the thermometer would stand higher than it does, and in the shade the temperature would be lower. We have an exact illustration of what would happen in what occurs on high mountains, or in balloons at great height. The higher we ascend the thinner becomes the layer of vapor interposed between the sun and ourselves. Under such circumstances the sun is scorching; its rays, nearly unopposed, exert a stronger influence upon persons and things and heat them highly, while the surrounding air is cold, as there is hardly any vapor to absorb solar heat. This fact has been well observed by Professor Langley during his ascent of Mount Whitney, and all alpinists have had experiences more or less similar. If, then, there were no vapor in the atmosphere, our summer days would, as is the case in high altitudes, be torrid and frigid at the same time—torrid in the sun, frigid in the shade, where the thermometer would certainly fall very low.

At night atmospheric vapor moderates radiation. During the night the earth gives off part of the heat it has received during the day, and this heat radiates into interplanetary space. When the sky is very clear and dry, radiation is considerable, and at all seasons a clear night is colder than a cloudy one, and night is colder in high altitudes where the overlying sheet of air and vapor is thin and rare, than in the lowlands, with a thicker atmospheric layer overhead. Radiation is unavoidable, because the temperature of celestial space is exceedingly low, probably inferior to 100° below zero (centigrade); but it is more rapid, and offers greater intensity when the air is dry and contains but a small quantity of vapor, because then the absorption by the atmosphere (by vapor, to be precise) of dark calorific rays radiated from the earth's surface is very slight. If there were no aqueous vapor in the air, a considerable cooling would begin as soon as the sun set, and such cooling does occur on high mountains and at high levels—in Thibet, for instance, which is both high and dry, and also in deserts, where the atmosphere is generally dry. In Sahara, after the hottest days under a scorching sun, the nights are generally very cool, and the thermometer runs down some 30° or 40° in a few hours. Such radiation and cooling must be very harmful, and most animals and plants could certainly not endure it. Vapor thus exerts a most beneficial influence,

as it moderates the heat of day and the cold of night, and acts as a sort of regulator, by means of which some uniformity is established under antagonistic and conflicting conditions, and in spite of contrary influences. Quite certainly, if vapor did not exist, the physiology of the animals and plants of the lowlands would be different, or they would perish.

The parts played by the numerous solid particles found in the atmosphere are as varied as is their nature. Physically pure air is a myth and can only be obtained artificially, in laboratories, and when great care is exercised. Even at the greatest heights, where micro-organisms as well as vegetable or animal fragments are few and often totally wanting, mineral dust is always found. These particles are very small, to be sure, and their origin varies: some are of volcanic origin, and after important eruptions, such as that of Krakatoa, volcanic particles are very abundant in the atmosphere and may be years in settling or falling on land or sea; others are merely dust which the wind has swept off the surface of the planet, and a large proportion consists of minute fragments of aerolites which have fallen into the earth's sphere of attraction from interplanetary space.

Professor Newton has attempted to form some estimation of the number of such aerolites, and he comes to the conclusion that our atmosphere receives the enormous total of some 20,000,000 meteorites per twenty-four hours, each of which is large enough to produce the phenomenon known under the name of "shooting star." However small these fragments may be—and yet in order to become visible because of the heat evolved by friction against the atmosphere they can not be so very minute—they certainly bring to our planet a considerable amount of foreign matter, a large proportion of which remains some time suspended in the atmosphere before falling. In all places where the requisite observations have been made, and where instruments have been placed for collecting the mineral contents of the air, there has been obtained an abundant harvest of meteoric particles, easily recognizable by their form and structure, and the mud which slowly accumulates at the bottom of the sea contains a large number of these extra terrestrial bodies. As a matter of fact, mineral particles of foreign source are constantly pouring through our atmosphere in the form of a dry and invisible rain. A large amount of terrestrial dust is also found in this rain. Von Richthofen speaks of the particular aspect of the atmosphere in a part of China, where the sky is yellow and opaque. When the wind comes from the direction of Central Asia, all things are covered with a yellow dust which is brought by the wind from vast regions whose soil is covered with a layer of ochreous dust, which is driven to great distances over the Pacific. In Australia, rains of a sort of red mud have been observed—rain made into mud by the admixture of dust, the latter having been transported by the wind and storm from considerable distances. Such a rain has

been noticed to fall over an area of 2,500 square miles. In the United States, a similar phenomenon has been observed. Prof. S. P. Langley, during the ascent of Mount Whitney, noticed that the middle strata of the atmosphere contained a large amount of red dust which was visible from above the level of these strata, while below, from the plains, no trace of it was detected by the eye. This dust had, perhaps, its source in China. The Krakatoa volcanic dust remained many years in the atmosphere and traveled many times entirely around our planet.

All this dust becomes easily perceptible to the naked eye, when we look at a ray of light in a dark room. But in order to well ascertain its origin, to know exactly what it is, microscope and aeroscope are wanted. By means of these instruments a very interesting microcosm is revealed. All sorts of particles are to be found in the air—small desiccated animals, such as worms, rotifers, vibrios, infusoria, fragments of insects, of wool, scales from the wings of butterflies, particles of hair, feathers, vegetable fibers, spores of fungi, pollen grains, flour, dust from the soil, and microbes. From our present standpoint many of these particles are of but slight interest to us, although it is a curious fact that volcanic dust may remain for years in the atmosphere at considerable altitudes, and travel around the earth with the winds, inducing those curious phenomena of light and color at sunrise and sunset which physicists and the public at large observed after the Krakatoa eruption. It is also a very curious fact, well illustrated by T. Aitken's investigations, that these particles are favorable to the production of rain. Under certain circumstances they play the part of a nucleus around which the vapor of the atmosphere condenses, and each particle becomes then the central part of a drop of rain.[1] What is of interest to us, from the biological point of view, is the presence of pollen grains, which explains how an isolated female plant may bear fruit even at a great distance from male plants of the same species; the presence of spores of fungi, which favors the dispersal of species; the presence of light seeds, which may be carried very far, and then fall to the ground, and develop an individual in a region where the species was never seen before. Again, the presence of microbes, to which we have previously referred, and which explains how many diseases are carried far and wide by the agency of the winds, such microbes being specially abundant in cities and in the vicinity of dwellings. At the Montsouris Observatory in Paris, M. Miquel finds between 30 and 770 microbes per cubic meter of air, according to winds, seasons, etc.; in the center of the town, Rue de Rivoli, the air contains 5,500 per cubic meter; in hospital wards, between

[1]Such being the case, in order to induce artificial rain, instead of trying to change the state of the atmosphere by means of explosions it would seem more rational to send dust into the heights. But at all events, the essential requisite is the presence of vapor, and this feature seems to have been sadly neglected in recent experiments. Nature provides rain by means of vapor and changes in temperature, not by explosions which can hardly have any influence.

40,000 and 80,000, while at 7,000 meters altitude, and above the sea at some distance from the shore, none at all are found. These figures are enough to show how the air under certain circumstances is a dangerous agent, and serves as a vehicle of death.

As we have seen, air is fraught with life as well as with death. Each of its constituents is essential to life, and each is also a cause of death. The one that appears to be the most vivifying of them all, becomes under certain conditions and doses, a fatal poison; the most useless, the most harmful is, when carefully investigated, an essential basis of the whole structure of life. And the general conclusion is that none could disappear, none could exist under a different form or in markedly different proportions, without soon altering the features of our planet and changing it into a naked and barren globe on whose surface no living being, of the present type, could be found.

If we study the subject more attentively we become aware of another fact. We perceive, to use again J. B. Dumas's very happy phrase. that all living beings are, at last analysis, nothing but condensed air, Plants exist mainly by reason of the existence of air, and animals and man can not exist without plants. The elements of plants are air, and animals live upon plants; the connection is direct and intimate, and man, therefore, is also only condensed air. And as this air, since the centuries during which mankind has existed, has been unceasingly migrating from generation to generation, from individual to individual, now part of some of our human ancestors, later returning to the atmosphere, and thus perpetually pursuing its cycle, our present organism is made of the same elements as that of our ancestors. Their substance is also ours. And this substance, which is also that of past animals and plants, goes on through space as an untiring wave. To-day or to-morrow a flower or a fruit, it will unite at one time to form a portion of a sluggish mollusk, at another to help build the brain of a Descartes, a Newton, a Pascal, a Shakespeare, a Helmholtz, a Joan of Arc. The cycle is never interrupted. No human eye witnessed its beginning; none will witness its end. It seems to be infinite and eternal—although, doubtless, it is neither—and alternating from life to death, as old as the world and yet as young as the newborn; if consciousness were among its attributes it would have gone through all that life may give—the highest joys, the deepest sorrows, and all emotions, the noblest as well as the basest.

The breeze which gently moves the leaves, the wind which moans through the high forests, is the sum total of all life that has been. It is the material of all that has had existence, of those that came before us, of those that are no more and for whom we weep. Now it becomes part of ourselves and to-morrow, perhaps, it will go on, pursuing its way, unceasingly metamorphosed from organism to organism without choice or favor, according to law, till the time comes when our globe, no longer heated by the cooling sun, shall slowly die. Then all the

substance of past living organisms will rest and return to earth; mortal cold and darkness will reign; the curtain will drop upon the tragedy of life, and that which remains will be a frozen and gigantic tomb, rolling silent and desolate through the unfathomable depths of the darkened heavens.

> I will encounter darkness as a bride
> And hug it in my arms.
> (*Measure for Measure.*)

THE ATMOSPHERE IN RELATION TO HUMAN LIFE AND HEALTH.

By Francis Albert Rollo Russell,[1]

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[Memoir submitted in the Hodgkins Fund Prize competition of the Smithsonian Institution, and awarded honorable mention with a silver medal.]

Part I.—Constitution and Conditions of the Air.

The atmosphere has been compared to a great ocean, at the bottom of which we live. But the comparison gives no idea of the magnitude of this ocean, without definite bounds, and varying incessantly in density and other important qualities from depth to height and from place to place.

Uninterrupted by emergent continents and islands, the atmosphere freely spreads high above all mountains and flows ever in mighty currents at levels beyond the most elevated regions of the solid earth. What is the composition of this encompassing fluid, and what its character? The work of the present century has gathered in a rich store of knowledge to answer the inquiry.

The atmosphere consists in the main of two gases, oxygen and nitrogen, and these are intimately mixed in the proportion of about 20.9 of oxygen to 79.1 of nitrogen by volume, and 23.1 of oxygen to 76.9 of nitrogen by weight.[2] These gases, which are each of them chemical elements, are not chemically combined with one another, but only mixed; each preserves its qualities, modified only by solution in the other. Gases have the property of diffusing among each other so completely, that no portion which could be conveniently taken, however small, would fail to represent the two gases in a proportion corresponding with that which they maintain in the whole atmosphere.

Another valuable constituent of the atmosphere, though varying greatly in amount at different times and places, is of no less impor-

[1]Author of "London Fogs," "Epidemics, Plagues, and Fevers; their Causes and Prevention," "The Spread of Influenza," "Observations on Dew and Frosts," etc.

[2]M. Leduc gives the weights as follows: Oxygen, 23.58; nitrogen, 76.42. Dumas and Boussingault give the density of nitrogen as 0.09725. (Comptes Rendus, 1890.)

tance to mankind than the two elementary gases which make up by far the greater part of the volume and weight of the whole. This is vapor of water, the result of the process of evaporation of those vast watery surfaces which are always in contact with the lower strata of the air.

Deprive the air of any one of these three main constituents and human life becomes impossible.

Next in rank from the human point of view is carbon dioxide, or carbonic acid gas, which, though comparatively very small in amount, exists throughout at least all the lower ranges of the atmosphere, and has the same close and necessary relations with plant life as oxygen has, or rather as food has, with the life of animals. It presents on a great scale an example of the wonderful law of gaseous diffusion; for, though much heavier than air, in the proportion of about 2 to 1, it diffuses under natural conditions nearly equably through every part, whether the region of its origin be near or distant.

Stated in tons, the following are the calculated weights of the chief substances composing the whole atmosphere:

	Billions of tons.
Oxygen	1,233,010
Nitrogen	3,994,593
Carbon dioxide	5,287
Vapor	54,460

In addition to the above, we find in the air a variable and very small quantity of ammonia, chlorides, sulphates, sulphurous acid, nitric acid, and carburetted hydrogen, but some of these depend, where detected, to a great extent on manufacturing operations and on aggregations of men and animals.

Liquids and solids in great variety are also very important, widely diffused, and constant ingredients in the atmosphere. The solids are everywhere present in the condition of very minute microscopic or ultramicroscopic motes or dust, composed chiefly of sea salt, or chloride of sodium, sand, or fine silicious particles, various dusts derived from volcanoes, factories, towns, and the remains of meteors set on fire in their passage through the upper air. Some of the most beneficent functions of these microscopic and invisible motes will be considered later. Other solids present in the upper air over a large part of the globe and in the lower strata, especially in the Arctic regions, are small particles of ice, condensed either in clouds or in air which appears nearly clear. Explorers in high latitudes relate that on fine cold days the air is frequently sprinkled with shining crystals of ice which seem to fall from a blue sky, and, on the other hand, in heavy gales and stormy weather the lower air is filled with a fine icy dust, resulting from the freezing of the spray torn from the sea waves. In temperate climates very much of the rain which falls on the surface of the earth has existed previously at high levels in the state of snow or ice particles. The experience of mountaineers and balloon voyagers, and, in a mountainous country, the sight of peaks covered with fresh snow after a

day's rain on the low ground, prove how commonly rain is melted ice or snow.

Other solid particles always present in great numbers in the lower air, and of great importance in relation to human, animal, and plant life, are various kinds of microbes, fungi, molds, and spores. At certain seasons the pollen of plants is very abundant. In some countries the air is thick in the dry and windy season with the dust of the soil. Agricultural fires cause a thick haze over parts of Germany, the United States, and other countries at certain times of the year. After great volcanic eruptions the air over many thousand square miles has been affected by a dense haze. This was notably the case in the summer of 1783, when, after an eruption in Iceland, terrestrial and celestial objects were dimmed by "dry fog" in western and central Europe during several weeks. In 1883, on the other hand, after the eruption of Krakatoa, near Java, the upper air, between 40,000 and 120,000 feet in altitude, was overspread with a semitransparent haze of a very remarkable character, consisting mainly of finely divided, glassy pumice. This haze stratum in the upper sky extended over all known countries and remained visible for several months.

Cloud globules are the most obvious and widely present liquid ingredients of the atmosphere. They possess properties of great interest in connection with the recently discovered ubiquitous atmospheric dust, with optical phenomena, and with the formation and distribution of rain.

The other familiar forms of water in the air are dry and damp fogs, mist, and rain. Haze is in most instances, at least so far as the present writer's observations go, in the south of England, a phenomenon depending on very small particles of water and on the presence of dust particles as nuclei.

Ozone, an allotropic and unstable form of oxygen, has been found to be constantly present, in very small quantities, in the open air in natural conditions, but can not be traced in the impure air of great towns, and is no doubt always greatly diminished where dwellings are thick together. Ozone consists of molecules, each supposed to contain three molecules of oxygen.

Peroxide of hydrogen is also supposed to exist in slight traces in the general atmosphere.

Minor impurities, arising from animal life, from manufacturing processes, and from the combustion of coal, are mostly not perceptible to the senses, except in the neighborhood of places where they are given off very abundantly.

The principal functions of all these various elements and substances of which the atmosphere is composed, may now be regarded in detail with special reference to their influence upon human life and welfare.

OXYGEN.

Oxygen, that wonderful element which constitutes very nearly half of the solid crust of the globe, combined as most of it is with the

metallic and other elements of the earth, forms also, in union with hydrogen, the great body of water which covers three-fourths of the terrestrial surface. Water consists of two volumes of hydrogen and one volume of oxygen chemically combined. Stated by weight, out of nine parts of water eight are oxygen. But water, as we know it, always contains other matter, and chiefly atmospheric air, which is dissolved in it, and to a considerable extent changes its character. For the service of man, water, deprived of air, would have lost several important characteristics. Oxygen is dissolved in water to the extent of 2.99 volumes to 100 of water at 15° C., an amount sufficient to support the existence of fishes and hosts of other aquatic creatures, and to oxidize and render innocuous some of the common impurities which result from animal and vegetable processes and decay. Probably its power when dissolved in the liquid is greater than in the atmosphere, and it must be compressed into a smaller space. Fresh charcoal absorbs eighteen times its volume of oxygen, and a much larger bulk of organic vapors, especially ammonia; in this condensed state the oxygen acts so powerfully as to unite with hydrogen to form water vapor, and with sulphur to form sulphur dioxide. We may thus assume that water, as we use it and drink it, has important effects upon the body which would not take place if robbed of its contained oxygen. As an instance of the value of the air contained in water for many domestic purposes, its assistance in the making of tea may be mentioned: if the air be allowed to boil out of the water the beverage is spoiled. Recent observation, however, shows that oxygen is not altogether removed from good water by the process of boiling.[1]

Oxygen has a very strong chemical attraction for the elements; only one is known with which it does not combine. Hence, "to burn" in common language means combination with oxygen, and most substances in the crust of the earth are already burnt, or combined with oxygen. In its ordinary form it has no color, taste, or smell, according to most observers, but recently a faint blue color has been detected as belonging to it, when seen in sufficient quantity. It has a small refracting influence on light, and exhibits a magnetic property, especially strong in the liquid form, to which it has recently been driven by intense cold and pressure. The degree of cold required was – 140° C. under a pressure of 320 atmospheres.

The proportion, by weight, of oxygen in the air has been determined by Leduc as 23.58 per cent.[2]

The volume of oxygen in the air in different localities and conditions has been tested by various observers. On the western seashore of Scotland the percentage was found to be 20.991; on the tops of hills, 20.98; in a sitting room (close), 20.89; at the backs of houses, 20.70; at the bottom of shafts in mines, 20.44.

[1] See Comptes Rendus, 1890. M. Muller.

[2] Comptes Rendus, 1890. A. Leduc.

The accurate determinations of Bunsen of the oxygen in the general air gave a mean of 20.93 per cent. Two hundred and three analyses by Reiset gave nearly the same result. Hempel found the amount at Tronso to be 20.92: at Dresden, 20.90; at Paris, 20.89. These amounts must be received with qualification, because in comparing one town with another more depends on the position in the town than on the situation of the town.

The average proportion of oxygen in the open country or at sea may be stated at about 20.95 per cent. In large, open spaces in London the amount of oxygen is nearly normal; in the streets, about 20.885; in Manchester, in fog and frost, 20.91; in the suburbs in wet weather, 20.96 to 20.98. These figures are merely approximate.

In the air of mines an average of 20 has been observed, and in extreme cases the amount was no higher than 18.6.

In the midst of vegetation on open ground, especially in the daytime, there is an excess of oxygen.

Angus Smith and others found the following quantities of oxygen in air in different situations:

On the Atlantic (Regnault)	20.918
In the Andes on Pichincha, about (Regnault)	20.949
Tops of hills, Scotland	20.98
Northeast shore and open heath, Scotland	20.999
Stockholm (Petersson and Högland)	20.94
Suburb of Manchester, wet day	20.98
Middle of Manchester, inclosed space	20.652
Manchester, fog and frost	20.91
Manchester, backs of houses and closets	20.70
Manchester, dense fog	20.86
Heidelberg (Bunsen)	20.924
Low parts of Perth	20.935
Swampy places, France and Switzerland	20.922 20.95
Bengal Bay, over bad water (Regnault)	20.387
Sitting room, rather close	20.89
Small room with petroleum lamp	20.84
Gallery of a theater, 10.30 p. m	20.86
Pit of a theater, 11.30 p. m	20.74
Court of Queen's Bench	20.65
Chemical Theater, Sorbonne, before lecture	20.28
Chemical Theater, Sorbonne, after lecture	19.86
In cow houses	20.75
In sumps or pits in mines	20.14
Worst in a mine	18.227
Very difficult to remain in many minutes	17.2

Recent experiments by Messrs. Smith and Haldane on impure air contained in a leaden chamber showed that with oxygen 20.19 and carbon dioxide 3.84 two men instantly got headaches on entering.

Oxygen is the breath of life, the element without which no human being could exist for a single hour. Brought into contact by every inhalation of the lungs, it revivifies the loaded blood, spreads over the

body the warmth resulting from its combustion with the carbon contained in the blood and tissues, and gives to the whole physical being a vigor and freshness which is impossible where the element is deficient. Thus to mankind it is life-giver, warmth-maker, and purifier. Unlike food, which may be taken irregularly and at long intervals, oxygen is a necessity at all times and in all conditions, in every hour of the day and night; and upon its reaching or approaching the normal quantity in the air around us, our health and enjoyment directly depend.

By the law of diffusion of gases, which causes the interchange of position of gases separated by a thin porous partition, the carbonic acid gas brought by the blood to the lungs passes out and is then exhaled, while the oxygen breathed into the air cells passes in through the walls of these cells to the blood. The heart sends the impure blood derived from the circulation through the body to the lungs: this dark blood is loaded with carbonic acid gas; the lungs return the aerated and purified red blood through their blood vessels to another division of the heart, which again drives the vivifying blood through the system. Experiments have shown that a similar change in appearance from dark to bright red blood can be caused by passing a stream of oxygen through the dark venous blood of an animal. That a process of combustion, or, otherwise put, chemical union, goes on at the same time, is shown by the fact that the blood is raised one or two degrees by its contact with oxygen. The oxygen in its course through the body combines with the effete or waste products presented to it by the tissues, and so the heating effect of combustion maintains the temperature of the whole body at the normal, about 98.6. The waste gases given off by the lungs consist of carbonic acid gas, water vapor, and a very small quantity of ammonia and other organic matters.

The average volume of air breathed in at each breath is about 30 cubic inches, and the volume of air which may be easily breathed in by an effort, and by expanding the chest, is about 130 cubic inches, or about four times as much. After a very full inspiration about 230 cubic inches can be expired by a man of average height and in good health. The total capacity of the lungs, however, is much more than this—about 330 cubic inches. Thus in ordinary quiet breathing we only fill about one-tenth of the available air space of the lungs. After every outbreath, or expiration, a quantity of air is left in the lungs. This residual air amounts to about 100 cubic inches.

An adult at rest breathes about 686,000 cubic inches in the course of twenty-four hours; a laborer at full work, about 1,586,900 cubic inches—more than double. The amount of air passing into the lungs has been estimated at 400 cubic feet in a state of rest, 600 in exercise, 1,000 in severe exertion. The number of air cells in the lungs is estimated at 5,000,000 or 6,000,000, and their surface at about 20 square feet. The epithelium or membranous film between the blood and air is exceedingly thin, and in many parts the capillaries are exposed, in the

dividing walls of cells, to air on both sides. The weight of air inhaled in the course of the day is seven or eight times that of the food eaten. The mechanical work of breathing represents energy expressed by the lifting of 21 tons 1 foot in 24 hours.[1]

From every volume of air inspired about 4½ per cent of oxygen is abstracted, and a somewhat smaller quantity of carbonic acid gas is at the same time added to the expired air.

Experiments on animals show that the amount of oxygen absorbed is very little if at all increased by an excess in the air surrounding them.

OZONE.

Ozone is an important constituent of the atmosphere, greatly contributing to its purity and freshness and to the vigor of human life. It is a form of oxygen in which the molecule is considered to be composed of three molecules of the gas.

Although existing in small quantity in the air, rarely exceeding 1 part in 10,000, the activity of ozone is so great and its function so beneficial that its presence in normal quantity is, in ordinary surroundings, a fair guaranty of the purity of the air and of healthy conditions so far as breathing is concerned. No ozone is found in the streets of large towns, in most inhabited rooms, near decomposing organic matter, and in confined spaces generally. In very large, well-ventilated rooms it is sometimes, though rarely, detected. Ozone is found in very small quantity a little to leeward of a large town. Even at Brighton, a town of about 110,000 inhabitants, ozone was barely discoverable on the pier when the wind blew from the town, but abundant when the wind was from another direction.

Ozone has the power of oxidizing to a much higher degree than oxygen, and vigorously attacks organic matter in a fine state of division. It is therefore a strong disinfectant. Its oxidizing power is the reason of its absence from confined spaces where organic matter, dust, or smoke is present, for such matter quickly uses up the small portion of ozone which enters with the fresh air. The walls, furniture, etc., are also covered with fine dust, which the ozone attacks. The difference we feel in going from a furnished room, however large, into the open air, is thus partly accounted for. There is somewhat more ozone on mountains than on plains, and most of all near the sea. Water is said by Carius to absorb 0.8 of its volume of ozone. An examination of sea water with a view to detect the amount contained in it would be difficult, but might give interesting results. A great excess of ozone is destructive to life, and oxygen containing one two hundred and fortieth part of ozone is rapidly fatal. The ordinary quantity even has bad effects in exacerbating bronchitis and bronchial colds and some other affections of the lungs.

[1] Professor Haughton, Carpenter's Principles of Human Physiology.

Ozone is formed by the passage of the electric spark, and especially of the brisk discharge through oxygen, and is therefore found in unusual quantity after thunderstorms. It may also be formed by the slow oxidation of phosphorus, and of essential oils in the presence of moisture; also by the decomposition of water by a galvanic current. When formed by electric discharge in air, it is quickly turned back again into oxygen, either by further discharges or by the action of high temperature, about 230° C.; at the temperature of boiling water it is slowly decomposed in moist air. Its pungency of odor is said to make it easily perceptible when only present to the extent of 1 volume in 2,500,000 volumes of air, and the smell may sometimes be noticed on the seabeach. It has been liquefied at 100° C. under 127 atmospheres pressure. In this form it shows a dark indigo-blue color: gaseous ozone looked at in a tube 1 meter long also shows a blue color. Thus there can be little doubt that, in conjunction with oxygen and fine dust, it contributes to the azure hue of the sky.

NITROGEN.

Nitrogen, the gas which constitutes four-fifths of the volume of the atmosphere, takes no direct part in the sustenance of human life, but has two great functions to perform: first, the dilution of oxygen to the proper and tolerable strength for respiration, and secondly, the supply of food material to plants.

Although life is possible for many hours in pure oxygen, it is hardly conceivable that the human constitution could be so modified as to endure for long an atmosphere of so actively combustible a character. At any rate, nitrogen is indispensable in present conditions to the human race. Plants, with few exceptions, do not absorb nitrogen from the air, and, indeed, in the case of most of these exceptions the supply of nitrogen is in a transitional compound form. Nitrogen is brought to the plants in general by processes of decay, and by the action of microbes in the soil, which rearrange organic elements, forming nitrates and nitrites. These nitrogen compounds are largely applied to the roots of plants as manure. Only one or two classes of plants can take up nitrogen from the air. Certain low algæ, freely exposed to light and air, seem to absorb nitrogen directly. Leguminous plants, such as peas, vetches, lupins, beans, clover, etc., absorb nitrogen from the air in a very curious way. Nodules or swellings are found on the roots; these contain minute fungi or microbes; the bacteria absorb nitrogen from the air, and, probably at the expense of the energy of the carbohydrates, etc., which they oxidize, supply this nitrogen in the form of compounds to the plant. These recently discovered facts open out the prospect of obtaining scientifically from the air, in some cases at least, the nitrogen which is now applied in combination with oxygen, soda, etc., as manure. If by the aid of special bacteria parasitic upon the plant we can systematically obtain the chief element of manurial

stuffs from the atmosphere itself, a great advance will have been made in agriculture and in the cheapening of food.

CARBON DIOXIDE.

Carbonic acid gas, or carbon dioxide, is found in small quantities everywhere in the air, and in about the same proportion at 11,000 feet as at the sea level. It is a colorless, transparent gas and does not support combustion or animal life. At 0° C. it may be liquefied under a pressure of 38.5 atmospheres. When liquefied and then allowed to escape it freezes into a snow-white solid in the air, and in a vessel under the vacuum of the air pump freezes into a transparent mass like ice.

One liter of carbonic dioxide at 0° C. and 760 mm. pressure weighs 1.97714, nearly double the weight of air, taken as 1.

At the ordinary temperature and pressure water dissolves about its own volume of the gas. Dissolved in rain it exerts in the course of time a very powerful disintegrating effect on rocks and minerals, so that the crust of the earth is greatly modified by the constant action of the solution.

The chief sources of carbonic dioxide in the air are the respiration of animals and the burning of fuel. A large quantity emerges from the earth in certain places, as in the Poison Valley of Java, and in many mineral springs, where it effervesces out of water escaping from pressure.

Saussure found the amount per cent in a wood near Geneva to be 0.0504 in the day and 0.0576 at night; in January, 0.0423; in August, 0.0568. In Geneva he found an average amount of 0.0468, compared with 0.0437 in the wood.

Schulze, Reiset, Levy, Armstrong, and Muntz, in different places, made several thousand observations, and the mean of all these shows during the day 0.0299, and during the night 0.0317. Reiset's long continued observations in the country 4 miles from Dieppe gave an average of 0.02942; and in June, above the crop of red trefoil, 0.02898; in July, above barley, 0.02829; near a flock of sheep, 0.03178.

Thorpe's very carefully conducted experiments agree well with the above values, and give for the air over the sea 0.03011. Armstrong, at Grasmere, obtained during the day 0.0296, and during the night 0.033. At the Montsouris Observatory the mean during 1877–1882 was 0.03.

In an unventilated barrack the following amounts have been recorded as the result of careful observations: 0.1242, 0.189, 0.195; in a hospital at Netley, 0.06 to 0.08; in the General Hospital, Madrid, 0.32 to 0.43; in a boys' school, 4,640 cubic feet and 67 boys, 0.31; in a crowded meeting, 0.365; in a schoolroom at Madrid, 10,400 cubic feet and 70 girls, 0.723; in a stable at Hilsea, cubic space 655 feet per horse, 0.1053.

It is not easily explained why the normal amount of carbonic dioxide in the free air has been so long assumed in scientific articles and text-books as 0.04 per cent, or 4 volumes per 10,000, when the best recent

observations show an average not exceeding 0.0317 per cent, even at night, and a general mean of about 0.0308, or 3.08 volumes in 10,000. All the most recent works on hygiene, however generally accurate, repeat this error.

Considering the value of small quantities in these measurements, especially where they affect human life, it is most desirable that the standard should be taken rather as 3 than 4 volumes per 10,000.

Although carbon dioxide does not itself support animal life, and we could do very well without it in the atmosphere so far as breathing is concerned, it is necessary to the growth of plants, and therefore through them an indispensable substance for the existence of the human race. The vegetable world not only needs a supply of this gas for its own sustenance, but by the selective action of its leaves keeps the air continually pure enough for the life of animals. Under the influence of sunlight every green plant absorbs the carbonic dioxide at its surface, breaks it up into carbon and oxygen, and returns some free oxygen to the atmosphere. In this way the two great kingdoms, the vegetable and the animal, mutually contribute, each to the other, the elements of life. The carbon drawn from the air, together with hydrogen and oxygen, forms the wood of the tree, the stalk of the plant, and the flesh of the fruit, and these, when burnt or eaten, again result in carbon dioxide and water.

The change from the compound gas to carbon and oxygen is brought about by small openings or pores filled with a green substance, chlorophyll, which during the daytime has the power to extract the carbon and set free the oxygen. At night, on the contrary, there is a slight expiration of carbonic dioxide, so that there is a real reason against keeping large green plants in a bedroom during the night. But the amount is very small compared with that exhaled by one person.

It is now known that plants, like animals, breathe oxygen from the air, while they use the carbonic acid as food.

About 1,346 cubic inches of carbonic dioxide are exhaled by a healthy man per hour. An adult gives off in repose about 0.7 cubic foot, and in active work about 1 cubic foot per hour. (Pettenkofer.)

It is a remarkable fact that this amount is much reduced when the air is already fouled with this gas; experiments showed that where the same air was rebreathed, as it often is, the reduction was from 32 to 9.5 inches per minute. Thus it appears that the elimination of waste products from the system is seriously checked by the presence in the air breathed of an excess of carbonic dioxide. Otherwise stated, air in crowded places may continue to sustain life while it fails to remove any but a very inadequate portion of the poisons with which the blood is charged.

The general surface of the skin of the body also gives out a considerable quantity of carbon dioxide, though, of course, very much less than the lungs.

About 67,200 cubic feet of carbon dioxide[1] are given off by the burning of every ton of coal. Since about 405,480 tons are burnt daily in England on an average (the quantity is much larger in winter), the air over the country receives daily about 24,728,256,000 cubic feet of the gas, or 1,200,000 tons.

The perfect burning of ordinary coal gas gives rise to 200 cubic feet of carbonic dioxide for every 100 cubic feet of gas consumed. Practically every cubic foot of gas burnt vitiates as much air as the respiration of one person. So that in a large town during the evening hours in winter the vitiation of the air is in main streets and in rooms many times larger than during the daytime.

Angus Smith, whose methods were not quite so precise as those later in use, found the following amounts of the gas in air in the situation described:

Hills in Scotland, 1,000 to 4,406 feet high	0.0332
Bottom of same hills	.0331
In the suburbs of Dundee at night	.028
In Dundee at night	.042
In London parks	.0301
On the Thames	.0343
Where fields began around London	.0369
In the streets in London in summer	.0380
In Manchester in usual weather	.0403
In Manchester in fogs	.0679
In workshops	.300
In the chancery court, 3 feet from the ground	.203
In the Standard Theater pit	.323
In very ill-ventilated Cornish mines	2.50

It appears from these figures that hill air, like that of the open country and of the seaside, contains little carbonic acid, but is not superior in this respect to the air of the central parts of large parks in towns. In the streets of a town the amount is decidedly larger by about 1 in 10,000 than the average amount of the country. During the prevalence of fogs, streets and confined places in towns often contain double the natural amount. The condition of the air of workshops, theaters, and crowded places generally is evidently foul and dangerous to health.

In the central parts of London, within the city, Dr. W. J. Russell found a mean of 0.0422 for three winters, and 0.0379 for two summers. During fogs the amounts were much higher, giving an average of 0.072, and on one occasion a measurement of 0.141 was recorded. The lifting of a fog was followed by a rapid decrease in the excess. On still dark days the amount was large. On fine days, in strong winds, and on holidays, the quantity was below the average.

The deficiency of oxygen and excess of carbonic acid, which are common to nearly all rooms, schools, churches, theaters, and workshops where many persons are gathered, are very favorable not only to the spread of various infectious diseases, but to the maintenance of a number

[1] Reduced to about the average temperature of the air in England, 50°.

of minor ailments; and where the exposure to foul air is prolonged, as in workshops, offices, and mills, to a continued depression of vitality. Various artificial means have been tried for improving the air of crowded rooms, and some are successful, but, on the whole, the direct admission of plenty of fresh air in currents directed upward and the removal of bad air by flues of sufficient diameter give in the long run the most satisfactory results.

The worst condition of air to which people are often exposed would probably be found in closed railway carriages. The capacity of an ordinary third-class compartment in England may be put at 240 cubic feet; it is certainly not greater. Containing 10 persons, it provides for each person 24 cubic feet of air at the beginning of a journey. Supposing the air to be unchanged, in the course of one hour each person will have breathed 17.7 of these cubic feet. Therefore, at the end of one hour 177 cubic feet out of 240 in the compartment will have been breathed out of the lungs of its occupants. Since an average man breathes out 0.6 cubic feet of carbon dioxide per hour, the amount of excess of this gas in the compartment at the end of an hour is 6 cubic feet; or otherwise stated, the amount in the air, instead of the normal proportion of 0.03 per 100 cubic feet, is 2.53 per 100 cubic feet. At the same time the oxygen is reduced and a quantity of organic poison and vapor is taken in with every breath. Practically, however, we must take into account the facts that from the first minute every person in the compartment breathes not a fresh parcel of air at every breath, but an already contaminated product, and that an excess of carbon dioxide has the effect of at once diminishing the quantity expired. Thus the amount of carbon dioxide would not be so large as that calculated, but may be estimated at one-half—1.26 per cent. But the deficiency in the carbon dioxide breathed out tells of carbon and other matters remaining unoxidized in the human system. The case of the compartment supposed air-tight is an extreme one and not quite exemplified in practice, but some approach to the condition described occurs in thousands of railway compartments on every calm, cold, winter morning and evening. Again, in traveling to the south of Europe in the winter of 1893 it was noticeable that 48 persons were shut up in one long carriage with a communicating passage between the compartments and without any efficient ventilation even through a hole or chink, the windows and doors all being made to fit closely. Twelve hours of breathing the same air would be likely to bring the occupants to a worse condition than where ten persons sleep in one small bedroom, which is about the worst case actually occurring in large towns. Moreover, these carriages are largely used by invalids and consumptives, and must become sources of infection to delicate persons.

Experiment by means of the sense of smell has shown that air in a room seems fresh when the carbon dioxide does not exceed 0.05999 per cent, a little unpleasant when the proportion is 0.08004 per cent, offensive and very close at 0.12335, and extremely close, when the sense of

smell can no longer differentiate, at 0.12818. In a railway compartment this amount is often greatly exceeded.

It is recognized by the best authorities that in order to keep the air in a room in a state good for respiration every person should be supplied with 3,000 cubic feet of fresh air in every hour. Thus, in an unventilated railway carriage occupied by one person, the whole of the air would require to be changed thirteen times an hour, and if occupied by ten persons, one hundred and thirty times an hour. Plainly, the ventilation provided by ventilators or by 2 or 3 inches of open window is incompetent to do this, and falls very far short of what is required when the wind blows in the same direction as that in which the train is moving, virtually resulting in a calm.

A space of 750 to 1,000 cubic feet in a room is properly required for each person, when the whole of the air is renewed by imperceptible and even ventilation about three times an hour. This standard is commonly not approached when several persons occupy a small room and windows and doors are closed. In a railway compartment the space for ten persons should be on the same scale—7,500 cubic feet, at least—and the air should be changed completely three times an hour, at least. As a matter of fact, the space is only one-thirtieth of this desirable quantity, and the whole air may in many cases be changed not more than three times an hour. Since the space can not well be increased, the alternative must be taken of largely increasing the flow of air through the compartment. Small, fixed openings above the windows and a ventilator in the roof would be the most efficient means of replacing foul air by fresh. The openings might be made to diminish in size in proportion to the strength of the wind encountered, and should be so situated as not to cause a perceptible draft. In rooms there is no better cheap ventilation for a mild climate than that obtained by thickening the lower part of the frame of a sash window so as to leave a space between the two sashes by which air enters and diffuses itself through the room, escape being provided by the chimney. Tubes of rather large size communicating directly with the outer air, and with their interior openings directed upward about 4 feet above the floor, are very satisfactory, and by means of a valve or damper can be regulated so as to admit more or less air, according to weather.

For large houses and cold climates, where more expensive apparatus may conduce to ultimate economy, a thoroughly satisfactory arrangement is the provision in the basement of a coke boiler with a system of hot-water tubes contained in a chamber into which fresh air passes, and is thence led through flues into the upper parts of the various rooms, where it becomes cooled and flows away with the products of respiration through openings near the floor into pipes connected with a shaft next the kitchen chimney, and so upward into the open air. But the boiler and stove require much attention, and the substitution of gas for solid fuel would sometimes be preferable.

Gas fires are good if the products of combustion are not permitted to

mingle with the air in the room, but carried off by the chimney, as with coal fires. The poisonous gases, etc., generated by combustion are very apt to cause sore throats, headache, and other ailments, and may favor the incidence of diphtheria. Carbon monoxide, which is given off by charcoal, coke, and gas fires in small quantities, is a strong poison.

VAPOR OF WATER.

The atmosphere of vapor of water coexisting with and interpenetrating the atmosphere of nitrogen and oxygen is of no less importance to human life. Its physical properties are very different and its characteristic is variety of state, while that of the dry air in which it floats is uniformity of state. Air is solid at —328° F. under a pressure of 1,000 atmospheres; vapor of water is solid at 32° F. under a pressure of 1 atmosphere. Recent researches have proved that cohesion, the force by which bodies are held together, increases as temperature is reduced. At the exceedingly low temperature of 328° F. metals and other solids are firmer than at any higher degree. Heat is therefore a force by which the molecules of substances in general are driven further asunder in the whole range of temperature. The force of cohesion is less in gases than in liquids and solids; and, indeed, is not manifested at all at ordinary temperatures and pressures. By great cold and great pressure, however, all gases but one have been brought to the liquid condition, wherein cohesion obtains the advantage over heat, and it is almost certain that by still greater cold all gases would be enabled to exist as cohesive solids. The habitable state of our globe depends on the adjustment of temperature and atmospheric density so as to permit the elements of life to maintain their appropriate gaseous and liquid forms. It is the large diversity of melting and boiling points in different substances which makes life possible. Uniformity, or even an approximation to it, would be fatal.

Water vapor, instead of being nearly homogeneous and of equal density at equal heights above the earth, varies greatly in quantity at different times and in different places. Like a gas, it tends to diffuse itself uniformly through the atmosphere as in a vacuum, but the resistance of the air has the effect of retarding the rate of diffusion. Owing, moreover, to the never-ceasing operation of unequal condensation and evaporation, the distribution of vapor is very unequal, both in time and place. The average quantity near the sea level in most countries is from 60 to 75 per cent of that required for complete saturation.

While air is always a mixture of gases in a fixed proportion, very far beyond any possible cause of liquefaction or solidification, vapor is never far from its condensing point; that is, however high the temperature and however low the pressure, a moderate amount of cooling will always bring it into the condition of water or ice. The repulsive force in the perfect gas, or in air, is sufficient to keep it gaseous at the lowest conceivable temperatures in natural conditions; the cohesive force in

water is sufficient to keep it, except to a comparatively small amount, in the state of a liquid. Yet this small proportion which flows through our atmosphere reaches the enormous weight of 54,460 billions of tons. Lighter than air, transparent, almost impalpable, vapor has an immense work to do in the sustenance of all that grows and breathes upon the surface of the earth. Like a good genius, it enables the air, the sunshine, the earth, to bring forth their riches, to cover the globe with verdure and gladness, and truly to make the desert blossom like the rose. Without vapor in the air, there would be no streams, no lakes, no wells. The land would be uninhabitable by man, except so far as fresh water might be condensed from sea water by machinery, and plants for his use be grown by the seashore. Even then the human system would hardly tolerate the parching influence of a perfectly dry atmosphere.

Water vapor, having a low temperature of condensation, was one of the last substances to fall, during the cooling of this globe millions of years ago, from the vaporous into the liquid condition, and consequently remains as a covering between the rocks, which were early solidified, and the air, which was not solidified at all. Water covers about three-fourths[1] of the whole area of the terrestrial ball. It has the remarkable property of being capable of existing in the gaseous, liquid, and solid states within a small range of temperature, and even of existing in all three states under ordinary conditions at temperatures which are common in winter over a large area, and which are easily borne by human beings.

In every cubic inch of water are many thousands of millions of millions of molecules, and all of these vibrate more or less rapidly under the stroke of heat. Some molecules, as a result of collisions among themselves, which are very numerous in every second, and as a result of their situation on the surface of the sea, are propelled with such velocity that they leap above the general surface, get beyond the retaining power of cohesion, and are taken up by the wind or by rising currents and carried aloft. The vapor rising from the water surface is warm, has in fact become vapor owing to being in more energetic vibration than the average of the particles of water. Moreover, vapor is lighter than air. So the lowest stratum of vaporous air near the tropical sea becomes lighter than the air above it for three reasons: First, by being in contact with the warm water which has absorbed the sun's rays; secondly, by being mixed with vapor which is lighter than the air it displaces, and thirdly, by this vapor coming from the warmest or most strongly vibrating molecules on the water plane.

The force of gravitation, it should be observed, is often of very little account where small particles such as these molecules of water are to be considered. A slight charge of electricity would be enormously more powerful in directing the motion of a single molecule. The reason

[1] The proportion of water to land is about 145,000,000 square miles to 52,000,000 square miles.

of this is that gravitation diminishes regularly with the size of particles of the same substance; but electricity, since it resides on the surface, diminishes at a much slower rate. It is likely that electricity would often cooperate with heat differences in driving the vapor from the surface in an upward direction. Evaporation is increased by low barometric pressure, so that an area of depression to some degree on this account tends to maintain itself.

By the beautiful law of the diffusion of gases, according to which each gas spreads itself through a space as if that space were a vacuum, subject only to retardation of the rate of diffusion by another gas already permeating the space, vapor diffuses itself through air, not with great rapidity, but so as to produce a fairly equable mixture in the same locality. The molecules of vapor have to encounter thousands of molecules of air in every inch and millions in every second of their progress, and if weather depended on diffusion, without the bodily transferences of large quantities of air horizontally and vertically owing to perpetually changing distributions of heat, the conditions of climate would be extreme and intolerable.

A very common form of exchange set up where the heat and moisture are not excessive by contrast with neighboring masses is by thin streams, filaments, or spirals of lighter vaporous air rising into the upper region, while colder filaments descend toward the earth or sea. This movement occurs under placid conditions, with cloudless sky, and when observed in temperate climates may be taken as a sign of considerable stability in the disposition of the atmosphere.

At other times, also commonly in fine weather, the warmer, lighter strata below break during the daytime into the upper strata by means of small columns, of a good many yards in diameter. These are often capped with rounded cumulus clouds where they attain an elevation and refrigeration beyond their dew point.

Occasionally, but rarely, the lower air breaks suddenly in a large torrential eddy, which may be several furlongs in diameter, into the upper region. The disturbance may give rise to a cyclone, whirlwind, or tornado. This occurs when the condition is abnormal, the lower strata being very moist and warm and the upper relatively cold and dry, and when from some cause, such as the prevalence of superposed winds, the interchange of differing air volumes has been delayed. The conflict of currents from different directions near the surface may then give rise to an eddy, and this will be a favorable occasion for a rush of light air, as through a chimney, toward the high level. Air flows in from all sides, but can not easily reach the center, owing to the earth's rotation, the onward movement of the whirl, and centrifugal force. In the present writer's opinion, a cyclone may be started or maintained by the strong wind, of 100 miles an hour or more, which often blows at a great elevation in the tropics and neighboring parts. At one observatory in the United States a velocity of 180 miles an hour has been

registered. The effect of a strong horizontal wind on a "chimney" of hot vaporous air would be to increase greatly the force of the upward torrent, as has been proved by anemometric experience with tall chimney shafts and domestic fires. The effect of the violent wind is exceedingly destructive, especially when the tornado is of small diameter. Some towns in the United States are particularly subject to these storms, and, as they generally come from one direction, the effect of building a perpendicular wall of 200 or 300 feet high on that quarter near the town, in order to break or divert its course, would seem worth trying.

Returning to the more normal conditions of the atmosphere, we may imagine the vapor, whether from land or sea, to have mixed much but not uniformly with the overlying air. The differences in the humidity of different masses or parcels of air, and the viscosity, friction, or resistance of the lower strata, where the pressure is 15 pounds to the square inch, prevent the interaction from being continuous and uniform, and consequently the ascending currents are local and variable, but when once fairly started, generally persist for a considerable time, moving all the while with the prevailing wind. When the vapor streams reach a certain height, they begin to condense, first and chiefly because they expand, and in expanding cool themselves, according to the laws of heat, and, secondly, because they mix with cooler strata. If the vapor be supposed to have ascended to a height of 3,000 feet, the pressure upon it has diminished from about 30 to 27 inches of mercury, or by about one-tenth, so that it swells, allowing for contraction by cold, to a bulk nearly one-tenth more than it had at the sea level. This is sufficient to produce a large diminution of temperature and the molecules vibrate so much less rapidly that some of them cease to maintain the condition of vapor. The vapor must condense, according to recent discoveries, not in contact with mere air, but upon very minute solid particles, motes, or dust, which may consist of ultramicroscopic sand, sea salt, or other material. So a cloud takes form. For each amount of curvature of a liquid surface there is a definite vapor pressure, and the pressure necessary for precipitation is greater as the surface becomes more convex, so that precipitation takes place more easily the larger the water globule in the presence of vapor. And so great is the pressure required for the condensation of vapor in free air that condensation can not take place except upon those small nuclei of dust which, more or less, are present throughout the lower atmosphere. Solid surfaces exposed to gases contract a film of gas upon their surfaces. Now, the dust of the air, owing to its minuteness, presents an enormous surface, and is moreover largely hygroscopic, so that the tendency to gather a film of vapor of water upon its surface becomes very important and effective. Without this fine dust in the air the world would hardly be tolerable or even habitable by the human race. The vapor would condense, not in the sky and in the form of clouds, but on the earth, on mountains, trees, houses, and clothes, so that the

sun's rays would strike down upon us oppressed with an air cloudless and saturated, and all objects would be perpetually streaming with moisture. An approach to such a state of things sometimes actually occurs on high mountains when the air is saturated and at the same time remarkably free from dust.

Clouds are often caused and maintained by mixture of winds or currents at different temperatures, the colder current reducing the temperature of the other below the dew point. Such clouds may be very wide in extent, but are not often dense, except in sudden and violent disturbances.

Radiation from a stratum of highly vaporous air may produce a cloud, and, when once formed, every cloud which has a clear sky above it radiates strongly and tends to maintain its existence by the consequent deposition of vapor upon its particles which it induces. The intensity of radiation into space depends largely on the dryness of the air above; and since dryness increases rapidly with height, the radiation from a high cloud is much more rapid than from a low one. Otherwise high clouds would dissolve much faster than they do in the rather dry air about them. If the heat of the sun's rays falling upon a cloud exceeds the loss by radiation, the cloud diminishes in bulk and density. Thus a fog frequently dissipates toward the middle of the day. But the farther the fog or cloud lies from the surface of the earth, the less is the heating effect of the sun, for loss by radiation proceeds faster and is not compensated by terrestrial warmth.

Sometimes, but rarely, cumulus clouds may be seen to precipitate fine rain suddenly, about sunset, owing to the sudden, uncompensated loss of heat by radiation. The appearance may be compared to a veil suddenly let fall which does not reach the ground. An example of this phenomenon occurred in the south of England on April 13, 1894.

The edges of clouds are always changing, and, in fact, a cloud is in constant process of formation and solution. Sometimes, especially in fine weather, or with a strong wind, the edges are hard, rounded, and well marked. This may be owing to a property which has recently been discovered to belong to aggregations of very small drops when moderately or slightly electrified—they attract one another. The higher regions of the air are strongly electric, especially in stormy weather, and the particles are held in proximity by mutual attraction and by the attraction of the mass of cloud.

Fog and clouds of a stratiform character, and cumulus clouds, and cirrus may commonly exist without rain, and in most countries there are many days in the year wholly overcast but rainless. This happens most often in quiet and uniform conditions of weather. There is no strong disturbance in the upper air; horizontal currents of somewhat differing temperature give rise to a stratum of cloud about their borders, and this soon evaporates when carried into the drier air above or falling into the warmer air below. Cumulus may often be seen to sink and

vanish at sunset, and stratiform cloud by itself is commonly the expression of moderate condensation under quiet conditions insufficient to precipitate vapor rapidly.

A cloud layer may continue for some days with strong wind, being caused by (1) a gradual ascending movement of the lower air so as to precipitate a small quantity of vapor continuously by expansion; (2) by contact of the upper surface of the lower current with a colder currant at a higher level; (3) by radiation from a rather moist stratum through dry upper air; or (4) by a warm, moist wind arriving, after a long passage, in cooler latitudes, and gradually becoming cooler by radiation and mixture.

In showery weather cumulus clouds are very often seen to consist of two or more masses at levels wide apart, and the upper mass, which is harder and firmer-looking than the lower, seems to move much less fast. Such clouds, even though heavy-looking, may pass over without rain, and it is generally, only by the appearance of rain in the air and landscape under them that they may be distinguished as actually shower-laden. Rain is, however, far more probable in these cases when the clouds are in tiers or separate layers; indeed, a single cumulus mass, simple and uncillified, seldom precipitates at all.

What, then, are the causes of rain; and why does it fall from some clouds more than from others?

The simplest and a very common cause of rain is the sudden elevation of moist air to a higher level, with the consequent chill by expansion. Standing on a mountain between the west and east ends of a loch in Perthshire, when a west wind is blowing, one may see showers frequently falling among the mountains westward, and failing to reach the flatter ground toward the east. The wind, even before it reaches the mountains, is tilted upward by the pressure of air in front of it, is consequently cooled, and precipitates moisture upon their western slopes. When the air descends in a drier and warmer condition toward the lower ground, the clouds quickly dissolve and thin out. The cloud-forming and the shower-forming effect is in general roughly proportional, between certain limits, to the height and steepness of the mountains. The great cliff called Slieve League, on the coast of Donegal, and the cliffs of Hoy, in the Orkneys, both about 1,800 to 2,000 feet high, cause clouds to be thickly formed sometimes fully half a mile to windward. Whether rain falls, and how heavily, depends chiefly on the moisture of the air and the coldness of the stratum into which it is forced.

A similar but little recognized effect is caused by opposing masses of air. Thus, let a moist warm southwest wind meet a cold northeast wind; the southwest wind is forced upward, especially over certain localities, and flows over the northeast wind, expanding very largely and rapidly and precipitating moisture heavily. The production of heavy thunderstorms may be fully accounted for by the local eddies

and conflicts between opposing winds, which occur in summer when the moist warm air-mass is lifted to great heights.

Generally, we may state the formation and amount of rain to be dependent on the following conditions:

(1) The height to which the lower air is forced upward.

(2) The amount of vapor in the lower and upper air, respectively.

(3) The relative coldness of the stratum into which the lower air is projected.

(4) The freedom from vapor strata and from cloud of the upper air, allowing free radiation from the rain cloud.

(5) The electrical condition of the air and cloud.

Where mountains are high, the air warm and moist and blowing toward steep slopes, very heavy rain falls either continuously at certain seasons, or in thunderstorms, according to the character of the winds, the heat of the sun on the earth, and to a less degree the temperature of the upper air.

The ranges of hills south of the Himalayas, the Himalayas themselves, the mountains of eastern South Africa, and the Andes give examples of such effects. High mountains have the power of precipitating as rain or snow even the rather small quantity of vapor which has passed over a continent, and thus the central areas of countries remote from the sea are provided with perennial fountains which flow down from the high ground and pass through the land as fertilizing rivers.

Another cause of rain is the radiation into space of the heat of vapor and of water particles at a height. Recent discoveries have revealed the fact that vapor does not condense into cloud globules in ordinary conditions without the presence of a very fine dust which floats in the atmosphere. When this dust radiates freely and moisture is deposited upon it, and when a cloud is formed, the upper surface of the cloud parts with more heat than the surrounding air, and the cloud globules grow in size by contact with vapor.

Now, throughout the process of increase in size, electricity is accumulated more and more densely on their surfaces, for the electricity of each molecule or particle resides on its surface, and the relative surface of a globule diminishes as the size of the globule increases. If the condensation be rapid, the particles formed are very unequal in size. Since surfaces only increase at half the rate of bulk, electricity is much denser on the large drop. Now, it has been found by experiment that large drops attract small ones when similarly electrified, and each addition further increases the attractive power of the drop. The large drops fall through a cloud at a much greater rate than the small particles and collide with many more droplets in the same time. In the course of a fall of 10,000 or 15,000 feet through cloud, the drops may greatly increase in size.

The sizes of drops vary from 0.0033 inch to about 0.1 inch. An ascending current of 3 miles an hour would sustain small drops;

only a very strong upward wind would sustain the largest. A hailstone of 2.58 inches in diameter would be kept at a height of about 15,000 feet by an upward blast of hurricane force, 100 miles an hour. Drops can never reach the size of a hailstone, for the resistance of the air has the effect of breaking them up. The smallest drops would take about six hours and forty minutes in falling from a cloud 10,000 feet high, but we know that this scarcely ever, if ever, happens. In reality the smallest drops falling on the earth are nearly always derived from a slight elevation and very small drops falling from a great height would, except in an extraordinarily saturated state of the air, evaporate in their course. Ordinary small raindrops take about six minutes or somewhat less in falling through 10,000 feet.

Raindrops are perfectly globular in form. This we know in two ways—first, from the rainbow, which can only arise from the regular dispersion of white light by transparent globules; and, secondly, by means of instantaneous photographs. The sphere is the figure of smallest volume which can be assumed, and consequently we find that free liquids under the influence of cohesion, surface tension, or gravitation, are always spherical.

Since a raindrop is an aggregation of cloud particles it contains a number of solid particles or invisible motes, and generally a very small quantity of sea salt. Besides this "dust" it attaches to itself soluble gases contained in the air, the result chiefly of animal life, of decomposition of organic matter, and of manufacturing processes. Thus, ammonia, nitric acid, hydrochloric acid, sulphurous acid, and a little air and carbonic acid, are found in rainwater. Brandes found an average of 26 kilograms of residue in every million of rain evaporated, the amount being greatest in January (65) and least in May (8). The residual substances were chlorine, sulphuric acid, soda, potash, magnesia, ammonia salts, organic matter, lime, carbon dioxide, oxide of iron, and oxide of manganese. The solid matter amounts in France to about 147½ to 156 kilograms per hectare. The importance of these minute traces of gases and other substances in rain is enormous, especially in relation to the nutrition of plants and the disintegration of rocks. But no less important to mankind is the function of rain in clearing the atmosphere of these ingredients. Clouds and rain are at the same time purifiers, filterers, and nourishers. In the words of the ancient declaration, "the clouds drop fatness," and "the water returns not void." The upper layers of earth have a remarkable power of purifying water, so that what is useful to vegetation is retained near the surface and the purified water passes down into deeper ground, where it may be drawn from wells or emerge in springs. The process, first of washing the atmosphere and then of self-purification, is so complete that though the mold swarms with organic life the water which has passed through this upper earth may be described as practically pure and free from organisms.

Not only is the raindrop a composition of solids, liquids, and gases, but it is of unequal consistency if the inner be compared with the outer part. Every drop surrounded by air is compressed into the spherical shape by an outer film of water which partakes of the character of an elastic skin. In the free air cloud globules and small rain can not easily coalesce on account of this elastic film enveloping them. They may impinge against each other, but unless the concussion be forcible they rebound. Similarly the drops falling from a fountain may be seen to run along the surface of the water like pearls before they unite with it. So also small drops of water falling from an artificial jet rebound and do not unite on collision. But let a stick of sealing wax be rubbed on flannel and held at a distance of several feet from the thickly falling drops; they at once cease to rebound, they unite into large drops, or else the jet keeps falling as a continuous stream and does not separate into drops as before. Again, let the drops be strongly electrified, they do not unite but repel each other.

Large drops attract small drops similarly electrified, and drops unequally electrified attract each other. The weak charge of similar electricity, which causes the globules to approach each other forcibly, is sufficient to break the enveloping film, but a stronger charge produces repulsion of the drops. In these observed facts we have what seems a very satisfactory explanation of some of the phenomena of thunderstorms; for example, the sudden heavy downpour and sudden cessation, and the apparent effect of flashes of lightning on the rain or hail. Finely divided water exhibits another property which is of great importance in the formation of rain, hail, and snow. Down to a very low temperature, 10° to 20° or more below the freezing point, according to the size of the particles, it resists congelation. This property is of immense effect throughout nature, and the life of plant and animals to a great extent depends upon it. When globules of water below the freezing point are touched by a frozen drop or by a snowflake they are instantly frozen. A crystal of ice is the most powerful of all substances in congealing water below the freezing point. Very many falls of rain, hail, and snow are due to this cause. The minute crystal as it descends through dense cloud gathers particles on its way until it has grown to be a large snowflake; and whenever the lower air is warm enough, snowflakes thus formed melt and fall as rain. Rain is much more often than we suppose melted snow. The minute flakes which would melt and evaporate if they did not meet with the water cloud, grow rapidly in the cloud, which would of itself be incompetent to precipitate.

When a flake of snow or kernel of ice falls through dense cloud, such as the towering cumulus which stacks itself to a great elevation in a thunderstorm, it electrically attracts the particles of unfrozen water, below the freezing point, through which it passes, and every particle attached and instantly frozen adds to the electric charge, so that more

particles are attracted with ever-increasing strength. In this way, in addition to mere impact, in the course of a fall of 10,000 or 15,000 feet,[1] are formed those large hailstones which devastate crops and kill animals. Taking Aitken's observations of the number of particles of water or droplets of fog, falling upon a square inch in a minute in a dense fog, as a criterion—say, namely, an average of about 10,000 droplets—and assuming that these drops fall at the rate of not more (it is probably much less) than 10 feet a minute, a hailstone falling through 10,000 feet of dense cloud would encounter if it began as a snowflake, 1 inch square, about 10,000,000 droplets, by mere impact. Some hailstones may result from the attraction of small spicules of ice and particles of water alternately as the nucleus passes through different strata, and these show concentric bands alternately opaque and clear. Similar bands may be formed by the passage of the hailstone through alternate spaces of thick cloud and of clear, unclouded, but saturated air. The latent heat brought into the sensible condition by condensation and congelation has been supposed to make such an accumulation in clear, saturated air impossible, but actual observation indicates that the rapid passage of the hailstone through very cold air speedily and continuously dissipates the heat thus set free. The appearance of spaces between successive tiers of dense cumulus cloud and the almost invariably excessive display of electric phenomena are characteristic of great hailstorms. It is very probable that between the dense clouds lie masses of saturated, or even supersaturated, almost dust-free air. A cold hailstone falling through these would accumulate ice in clear, alternate zones surrounding the nucleus. Large hailstones are generally spheroidal, small ones conical, with icy bases and a softer apex. The large hailstones are probably more dependent on electric attraction, and the small on the impact of descent, for their form and icy accumulations.

In a thunderstorm or shower, the lower clouds are generally negatively and the upper positively electrified. Before a hailstorm clouds of great significance may be observed, which may be described as turreted cumulus or cumulo-stratus. They are quite distinctive of hailstorm weather, though of course the hailstorm may not occur in the district where they are seen. They consist of hard-looking, sharply defined, generally white, and rather small masses of cloud, with projections towering upward and rather broader at the top than at the base, or equally broad. These peculiar clouds are worthy of note with the view of forecasting the probable occurrence of hailstorms.

Vapor, when it ceases to exist as a gas in the air, assumes several

[1] The height of cumulus cloud may often be well observed and measured not only from the plain, but on mountains. The tower of cumulus cloud often exceeds 10,000 or 15,000 feet, and in great storms may be 25,000 to 40,000 feet from base to summit. Both observations from the earth and balloon ascents supply evidence to this effect.

different forms which are only obscurely understood. There seems to be a stage between the gaseous and the misty in which vapor is condensed into very minute transparent motes or into a condition corresponding to the critical state, the viscous interval, observed by Andrews in carbon dioxide under great pressure. Just above this critical point this gas behaved to some degree like its vapor and liquid below it with regard to pressure. The behavior of water vapor under varying pressure and when near saturation at different temperatures would be an interesting though difficult subject for research. Dry vapor is regarded by some experimental observers as diathermanous, like air; yet we certainly find that what seems to be invisible transparent vapor does largely arrest radiation from the earth. Therefore, it would seem much of the vapor of the air, when near saturation, must be in a condition bordering on mist or finely divided water. Only beyond a certain size, maybe, or when dust is thick, do the particles become large enough to give the effect of haze. It often happens that a thermometer freely exposed to the sky on a fine night suddenly ceases to fall, and rises several degrees without any apparent cloudiness or diminution of the luster of the stars, but this rise, in the present writer's experience, is a good indication of approaching rain after dry weather. Whether the screen in the upper air which reflects the radiation from the earth be a thin cloud or else vapor in a state of inchoate condensation, has not yet been ascertained.

Haze, fogs, and clouds are caused by the tendency of vapor to condense upon solid particles below a certain temperature. A change of state from vapor to liquid or liquid to solid occurs much earlier in the presence of "free surfaces" of other bodies than where these are absent. Saturated air, as we call it, can hold no more vapor in ordinary conditions, but apart from solids and dust particles it could contain much more vapor without precipitation. Similarly, if water could be heated by itself apart from solids and contained gases, it would rise high above the boiling point without boiling, and would eventually explode; so also the droplets of a cloud do not freeze, though many degrees below the freezing point, until they touch a solid object. Dust in the air offers the free surface which is required for condensation. Different kinds of dust differ greatly in the power of compelling deposition. Sulphur, magnesia, and common salt are, in the laboratory, at any rate, powerful fog producers. In the open air sulphur seems to have little appreciable effect; but salt, which is hygroscopic, or damp-attracting, and pervades the atmosphere, plays an important part. Smoke, again, or finely divided tarry matter, greatly favors fog formation, owing, probably, to its strong radiative capacity and to its coating the water globules so as to prevent evaporation.

Suppose the motes of dust or salt in heterogeneous air to be radiating freely, and therefore to be colder than the air, and suppose each of them to be frequently brought in contact with filaments of air and

vapor at a higher temperature than the average, then it is conceivable that momentary deposition and reevaporation may occur. The result would be haze. With fairly homogeneous masses of air, as with a west wind, the contact of warm and cool air occurs here and there on a much larger scale and at once produces massive clouds, owing to the quick growth of particles in a moist air brought in block below the dew-point by ascent or otherwise. The interchange between differing air masses is in this case by large columns instead of by infiltration and filaments. The steam leaving the escape valve of a boiler at high pressure is at first invisible, then bluish and semitransparent, like haze, then opaque and white, like cloud. The influences which cause haze maintain the vapor in the second stage; it passes perpetually from molecular invisibility to the verge of particulate visibility and back to invisibility by swift evaporation. Clouds, on the contrary, result from cooling in large masses, as by ascent, and the humidity is too great to permit so rapid a return to the condition of vapor within their borders. When they evaporate they become invisible at the edge without perceptibly passing through the stage of haze.

Why the process of change of size of the particles differs so much in different states of weather is by no means clear.

Haze has long been a meteorological problem. If it be vapor, why does it so frequently occur in the driest weather? If it be dust, why should dust continue to affect the atmosphere in such excessive quantities during particular periods, often in calm weather, and with a gentle wind from uninhabited areas, either sea or land? The moistest winds are generally the clearest, the driest are the haziest.[1] Moreover, there is a thick haze which sometimes persists for many days in spring or summer in England, and neither increases nor diminishes perceptibly during the night, when radiation is active. In such weather the air is dry, and the wind, if any, commonly a light air from between east and north. Since neither the sun's heat nor the nocturnal cold affects it, we must ascribe it to one of two things—the presence of a large quantity of dry dust in an unusual state, or the development of vapor condensation in some unusual way, so as to depend little on the general temperature. On the top of Snowdon, 3,300 feet, the present writer has observed haze as thick as on the ground level, and extending 1,000 or 2,000 feet above the summit. It was similar, though less in degree, to the obscuration described in the annals of last century as having covered Europe for months after the great eruption of a volcano in Iceland in 1783. Mr. Conway has recently observed high above the Himalayas a sudden haze overspreading the sky like the smoky haze seen near a large city in England. The explanation probably is that the haze depends on the relative temperature of mixed portions of strata of air, and much less on the general air temperature.

Aitken has shown that when the wind blows from inhabited places

[1] In England.

there is both more haze and more dust than when it blows from the sea or from uninhabited country, and in Switzerland a thick veil of haze seemed to hang in the air between the observer and the mountains on all days when the number of particles was great, and it became very faint when the number was small. When the wind blew from the plains the air was thick; when from the Alps, clear. Similarly, at Ben Nevis, on the northwest coast of Scotland, a northwest wind was clearest, a southeast wind haziest, and the dust particles were generally more numerous according to the amount of haze. "Of 'purifying areas' the Mediterranean gave for lowest values 891, the Alps 381, the Highlands 141, and the Atlantic 72 particles per cubic centimeter. Dampness of the air was found to increase the effect of dust, so that nearly double the number of particles are required to produce the same amount of haze when it is dry than when it is dampish." When the depression of the wet-bulb thermometer below the dry bulb was 2° or more the transparency was roughly proportional to the wet bulb depression; that is, to the dryness of the air. "The nearness of the vapor to the dew-point seems to enable the dust particles to condense more vapor by surface attraction and otherwise, and thus by becoming larger they have a greater hazing effect." The number of dust particles in square centimeter lengths of 10 to 250 miles required to produce complete haze in air giving different wet-bulb depressions was calculated to be as follows:

Wet-bulb depression.	Number of particles to produce complete haze.
Degrees.	
2 to 4	12,500,000,000
4 to 7	17,100,000,000
7 to 10	22,600,000,000

Since more particles are required to produce haze in dry than in damp weather, it becomes the more remarkable that thick haze is so common in dry weather and generally absent in a moist atmosphere.

The observations of the present writer for many years have shown that haze is most apt to occur when there is infiltration or mixture of differing air currents, and indeed that it generally expresses the juxtaposition and mixture of winds. A steady wind extending to the upper clouds is very seldom hazy, and, on the other hand, haziness may be taken as a sign of the existence of another wind above that prevailing near the ground, or of variable currents. So much is this the case that in southern England a hazy or misty east wind signifies generally a rather short period of its prevalence, but a clear east wind means continuance. Of course care must be taken to be situated on the windward side of thickly inhabited districts in making such forecasts. It seems, therefore, that when haze is not due to a large amount

of dust, it must arise from some effect of the mixture of different currents. A wind from the Atlantic on the west coast of Great Britain generally has a west wind above it, and is fairly homogeneous, but an east wind generally has to encounter and drive back a westerly or southerly wind, and has an opposing current within 3 to 7 miles above. There must in these cases be a great deal of mixture of portions of air of different humidity, temperature, and electrical tension. The contiguous parcels of air produce at a number of points momentary deposition of vapor on dust particles, and the resulting effect is haze. The dew point is attained in the molecular environment by momentary contact of cold, dry, dust-bearing with moist, warmer, less dusty air.

It is well to bear in mind the large extent and small depth of the whole of the lower region of winds. Currents of air, say within 25,000 feet of the surface, extended over a territory 400 miles square, would be represented by a layer of water an inch deep in a basin 80 inches square.

On the east coast of Scotland an east wind often brings a thick haze which may last two or three days, and is followed by rainy weather. But a much less thick blue haze prevails during fine weather, with light or variable easterly breezes, both in Scotland and England. The density of the haze in these conditions depends less on the number of dust particles than on the mixture of differing currents and on the moisture and warmth of the one current, the coldness and moisture of the other. There is no reason for supposing that a wind blowing from the polar regions and over the breadth of the North Sea is heavily charged with dust, yet the haziness is as great looking seaward as over the land of Berwickshire or Fife.

The clear air of continental climates, such as the European and North American, is partially explained by the moderate amount of dust, the infrequency of a condition approaching saturation in the lower air, and the absence generally of local winds such as are produced by a varied distribution of land and sea. Haze is very often the result of the passage of air over water of a lower temperature, and the difference of the temperatures may decide whether the obfuscation shall be haze, fog, mist, or fine rain. No amount of dust is in general competent in a dry, uniform air to produce apppreciable haze beyond what is due to its own particles. Thus in Colorado there is often a great deal of dust in the air, but the air is clearer at such times than it commonly is in England; in the Punjaub dust winds obscure the air for a long distance; in the Sahara Desert there is often thick dust, but the hazing is not great except with strong wind; when, however, this dust is blown far out over the Atlantic, the haze becomes very considerable, and is a common phenomenon about the Cape de Verde Islands. Towns, again, such as Paris and Pittsburg, which produce a great deal of dust, by the test of the dust counter, are not affected by haze in clear, dry weather, and even London, in some states of the air and very often at

night, is only covered by a barely perceptible light haze. But coal smoke, commonly has the effect of causing a very persistent haze, and this, in the case of London, spreads conspicuously with the wind to places distant 100 miles or more. Coal smoke, we must remember, is accompanied by a good deal of water vapor and sulphurous acid. Gas and wood, when burned in large towns, produce no fog and very little haze, though the dust counter might show as many particles as where coal is burned. Dust in general may therefore be acquitted of taking an important part in producing any but a light, thin haze, except where there is a mixture of currents at different temperatures, and then some haze would in most instances be produced in any case by the normal average amount of very fine dust which exists everywhere in the atmosphere. In clear, homogeneous air, even near saturation, much dust or smoke may be added to the air without causing haze; in dry, hazy air much dust may be added without much intensifying the haze. In certain conditions of wind and weather much haze may exist without an abnormal quantity of dust, and, except on rare occasions, there is always enough dust, maybe of almost molecular dimensions, in the lower strata of the air to admit of precipitation of moisture where conditions are otherwise favorable.[1] A great deal of this dust probably consists of chloride of sodium, or sea salt.

The following instances may serve to show how haze and cloud are successively formed by a conflict of differing currents of air. St. Fillans Hill is a small, steep, isolated, conical hill about 300 feet in height, standing in the middle of the valley of the upper Earn, in Perthshire, about 2 miles from the lower end of Loch Earn, and flanked by mountains about 2,000 feet high on each side of the valley. The author was on the summit about 5 o'clock one evening in August,[2] when the breeze, which had been blowing freshly from the west, with a clear air, suddenly began to slacken, and in about five minutes dropped altogether. Then down the valley, eastward, a blue haze began swiftly to climb the glens tributary to Strathearn, and the whole air eastward grew obscure. The calm only lasted a little more than two minutes, and then suddenly a strong wind from the east set in, and soon the air westward as well as eastward had turned thick. The east wind continued, and in a few minutes the tops of the hills rising precipitously from Strathearn to a height of about 2,000 feet were obscured with cloud banners which grew continuously, and descended till in about two hours not only the hills above a level of about 1,000 feet, but the whole sky, was covered with gray clouds. The duration of the neutral calm corresponded with the time usually occupied, according to my observations in the neighborhood of London, by a moderate east wind in driving back the opposing current. At Richmond, and between Richmond and London, such a

[1] These observations are derived from many years' attention to the conditions of prevalence of haze and fog in and near London.

[2] About 1877 or 1878.

change is signalized in the neutral band of calm by a dense yellow haze, producing great darkness in winter, the result of a banking up of smoke to some altitude, together with the condensation of vapor by the mixture of currents differing in temperature. The darkness in such a band lasts much longer with lighter winds, and I have known a west wind to prevail at Richmond simultaneously with an east wind in London, both without fog, while at Wandsworth a calm continued for many minutes with dense, almost nocturnally black smoke fog, the pressure in each direction being apparently equal.

FOG, SMOKE, GASEOUS AND SOLID IMPURITIES IN THE AIR.

FOG.

Fog is the result of one or both of two principal causes. The first is active radiation into space from the earth and from the air contiguous to it, and the second is a mixture of winds and currents, or of vapor and air at different temperatures.

1. Radiation fogs occur commonly when the atmosphere above the lowest stratum is cold, dry, and nearly still, and when the lowest stratum is greatly cooled by contact with the cold radiating earth, and therefore precipitates vapor into the form of minute globules of water. These globules themselves have a large radiative capacity, so that they tend further to reduce the temperature of the air in which they float, which has no such capacity. The stratum of fog so formed, not extending very many feet above the ground, fails to reflect much of the heat radiated from below, and quickly disperses, by radiation into space, whatever heat it absorbs. Thus earth and fog continue rapidly to part with their heat through the clear sky into space. The stratum of fog often grows in height and density through the night, and continues till about noon of the following day, or disperses in the late hours of the morning. If extended over a plain and watched from a height above the upper level, a fog of this character, in somewhat damp and not typical radiation weather, may be seen gradually to move irregularly upward under the influence of the morning sun, and in various directions to present prominences like those of the upper edge of cumulo-stratus. Smoke issuing from a tall factory chimney rises through and above the fog, but in a very short time falls back upon its surface and meanders like a dark river on a white ground.[1] The persistence of the fog depends upon the coldness of the ground, which is shielded from the sun, and upon the very large difference of temperature, sometimes 10 degrees or more, between the fog and the stratum of air a few feet above it. When, however, the sun's heat absorbed by the water particles exceeds the heat lost by radiation, the fog lifts, that is, its uppermost stratum rises, owing to diminished specific gravity, and

[1]These observations were taken during the prevalence of a ground fog, in the country surrounding the Malvern Hills, in February, 1890.

either clears at once or remains for some time as a light blue haze.[1] The strata below it, submitted to the same influence, successively rise and take its place, and the evaporated moisture mingles with the general air.

Fogs of this kind locate themselves in low-lying valleys, basins, and plains, for the air, chilled by contact with the radiating ground, sinks by gravitation into such situations and in them is least likely to be disturbed. Sometimes a white fog may be seen pouring down an open and rather steep ravine like water.[2] Slopes of hills, especially their southern sides, some hundreds of feet above the plain, are comparatively free from these fogs, and are much drier and warmer during their prevalence than lower places in the neighborhood. Such an elevation is more favorable on this account to the human constitution; both the daily and yearly thermometric range is much smaller. Dense fog and frost often remain throughout the day on the northern side of hills when the southern slope is bathed in sunshine. This has been observed on several occasions on Hindhead, Surrey, the air in the fog keeping much colder than the air above it and on the southern slope.

In the still air which precedes and accompanies radiation fogs the number of dust particles is high above the average, owing partly to their becoming gathered by undisturbed precipitation into the lowest strata. On several occasions when the dust particles were counted they amounted to between 45,000 and 80,000 per cubic centimeter. Each of these is a nucleus for the deposition of vapor. The water particles are so small that they evaporate before touching solid objects during the daytime, the objects being warmer than themselves. For this reason these fogs have no wetting effect. In a fog, when objects were invisible at 100 yards distance, 19,350 droplets sometimes fell on a square inch per minute, but the average was much less than this, and the smallest number about 1,900 per minute.[3] The large number of particles favors the formation of fog. Considerable numbers of living organisms no doubt exist among the water particles of the fog, but are not known to be a cause of ill-health in the country remote from towns. Nor is great cold combined with fog productive of much illness in the country. In smoky towns the case is far different. Thus, in London the death rate was raised in a single fortnight, from January 24 to February 7, 1880, from 27.1 to 48.1 per thousand. The fatality and prevalence of respiratory diseases were enormously increased. The excess of deaths over the average in the three weeks ending February 14 was 2,994, and in the week ending February 7 the deaths from whooping cough were unprecedentedly numerous—248—and from bronchitis numbered 1,223. At least 30,000 persons must have been ill

[1]This haze may be taken to be caused by the aggregated nuclei of dust left after evaporation of the water which condensed upon them.

[2]This was seen by the author with remarkable distinctness near Alum Bay, in the Isle of Wight.

[3] Aitken.

from the combined effect of smoky fog and cold. The present author was in London during the whole period, and noted especially the unusual number of days during which the darkness and stillness continued, and the tenacity with which the fog clung to the cold ground on the shady sides of squares and streets, when a warm, gentle current from the south improved and cleared the air above a height of 20 or 30 feet.[1] The large excess of carbonic acid, of sulphurous acid, and of micro-organisms and effete organic products was partly concerned in these ill effects, but the factor of greatest importance was the finely divided and thickly distributed carbon or carbonaceous matter, which irritated the breathing passages and lungs. The results corresponded rather closely with the more gradual ill effects of dusty trades. The lungs of a man who has spent his life in London or Manchester are found, post mortem, to be choked with black matter. In some parts of London there is sometimes no more light at noon than in the darkest night. After a fortnight of dense fog the deaths in London for one week, ending January 2, 1892, exceeded by 1,484 the average number, being at the rate of 42 per 1,000. Increases took place in the following diseases: Measles, 114 per cent: whooping cough, 173; phthisis, 42; old age, 36; apoplexy, 58; diseases of the circulatory system, 106; bronchitis, 170; pneumonia, 111; other respiratory diseases, 135; accidents, 103.

These results are in the main attributable to the concentration of the ordinary constituents of London air, with moisture and intense cold to help their deadly work. The majority of the fatal cases were in weakened constitutions, though many were among the robust. The experience of large towns always is that the power of recovery after illness is much less within their confines than in the country. In the fog the evil influences of town air are many times multiplied. The blackest fogs, which are local, are the result of variable or opposing currents which carry up the discolored mass to a height of hundreds of feet, where they condense their moisture in a stratum of unusual thickness or height. By a converging flow of currents, a huge column of blackened fog particles rises vertically to a height where it may remain or whence it may move slowly from place to place. A fog need not always be resting on the ground, but may hang after the manner of stratus cloud at some level, often a few hundred feet above it. This happens when the ground is not much colder than the air. The smoke of a steamer may be seen sometimes thus to form a dark streak, remaining about the same level for an hour or more. That domestic fires at least rival manufacturing works in the production of dark fogs is proved by the intense darkness which has prevailed in London on Sundays, and once on Christmas Day. Factory fires are out on Sundays, but domestic fires are larger and more numerous. Smoky fogs invade houses and even warm rooms, showing that many of the nuclei are solid particles large enough visibly to obstruct light even when dry.

[1] London Fogs. R. Russell. Published by Stanford, London, 1880.

At a distance of 10 miles from London, the smoky particles are small and show quite a thick haze in a room with a fire, when a gentle current is moving from the town. Professor Frankland has shown that if a little smoky air be blown across the surface of water evaporation is retarded 80 per cent. The water globules may be similarly coated with tarry matter, which hinders the warmth of the sun from evaporating them. Moreover, every particle of carbon is a good radiator and in the early morning tends to increase the cold in the air around it; moisture is deposited upon it, in the opinion of the present writer, and can only with difficulty evaporate, so long as radiation is active and while the heat and light of the sun are stopped by smoke. The effect of finely divided carbon in stopping light may be tested by holding a piece of glass for a few moments above the flame of a candle; the black film deposited enables us to look at the sun easily, and it appears well defined, like a red orange, as in a fog.

The imperfect combustion of coal is the cause not only of fogs being specially dangerous to life, but of their persistence in duration far beyond those of the surrounding country. The removal of coal smoke would mean much less fog and much less evil in that which remained. Cities which use wood as fuel, or anthracite, or gas, or oil, are no more visited by fogs than the surrounding country, although the fine "dust" above them is, according to Aitken, very greatly in excess of the normal.

Pittsburg had a black climate till it used natural gas, and thenceforward has had a clear air, and no special liability to darkness and fog. In London, of 9,709,000 tons of coal used annually, about 1 per cent escapes into the air unburnt and 10 per cent is lost in other volatile compounds of carbon. The bright sunshine, compared with that of Kew, 9 miles distant, was, in the four years 1883–1886, 3,925 hours, against 5,713 at Kew, and about 6,880 at St. Leonards, about 80 miles distant. From November, 1885, to February, 1886, inclusive, the sunshine in London was 62 hours, at Kew 222, and at Eastbourne 300.

Town fogs contain an excess of chlorides and sulphates, and about double the normal, or more, of organic matter and ammonia salts.

During the last fortnight of February, 1891, the previously washed roofs of the glass houses at Chelsea and Kew, the former just within, and the latter just outside, London, received a deposit from the fog, which was analyzed and gave the following results:

Substances.	Chelsea.	Kew.
	Per cent.	*Per cent.*
Carbon	39	42.5
Hydrocarbons	12.3	4.8
Organic bases (pyridines, etc.)	2	....
Sulphuric acid (SO_3)	4.3	4
Hydrochloric acid (HCE)	1.4	.8
Ammonia	1.4	1.1
Metallic iron and magnetic oxide of iron	2.6	....
Mineral matter (chiefly silica and ferric oxide)	31.2	41.5
Water, not determined (say difference)	5.8	5.3

The weight of the deposit was at Kew 30 grams in 20 yards. At Chelsea the same area gave 40 grams, which is equivalent to 22 pounds to the acre, or 6 tons to the square mile. A large proportion of the deposits of fog in smoky towns clearly arises from the imperfect combustion of coal. On plants the deposit is sticky, like brown paint, and is not washed off by water. A country fog is harmless in a greenhouse; a town fog most destructive, killing soft-wooded plants, and greatly damaging others. A very large number of plants will not thrive in smoky towns. In Manchester, the deposit collected from aucuba leaves gave 6 to 9 per cent of sulphuric, and 5 to 7 per cent of hydrochloric acid, mostly in a state of combination. Three days' fog deposited per square mile 1½ hundredweights of sulphuric acid and 13 hundredweights of blacks.

Among the results of smoky air in towns may be mentioned: The discouragement of cleanliness and ventilation; the constant deficiency of light; the damage to plant life, so that only a few trees and plants can live; the destruction and disfigurement of stone, cement, iron, paint, wall papers, clothing, etc., and the depressing effect of dirt and blackened streets on the people; losses to artists of all kinds who depend on light: the lowered vitality of a large portion of the population, and a contributory influence toward the rapid degeneration and extinction of town families.

In London the extra expenditure entailed is about £1 a head, or more than the value of all the coal burnt in houses. The extra washing, painting, and repairs, and the loss of unburned carbon, etc., are among the principal items in the account.

The intensity of the ground fog depends largely on the amount of cooling which the earth has previously undergone. At the beginning of February, 1880, the ground in London was hard frozen with the intense frost which had prevailed for some days. A moist southerly current supervened and the temperature rose several degrees above the freezing point. On the shady side of squares the fog then produced between the ground and 10 or 20 feet above it was so dense that at 10 a. m. a lamp-post 4½ yards distant was invisible. In an ordinary thick fog, such as that of January 11, 1888, objects are visible at thirteen times that distance. Above the shallow stratum of ground fog the air was nearly clear and the smoke escaped.

Such fogs are due partly to radiation into space, but also largely to the mixture of the warm current with air which has become cold by contact with the ground, and to radiation toward the ground.

All radiation fogs disperse or greatly diminish when the sky becomes clouded and reflects some of the warmth radiated from the ground. They are not formed under a cloudy sky.

2. Fog is frequently produced, sometimes on an enormous scale, covering an area exceeding that of the British Isles, by the mixture of opposite currents of small velocity. The condition of atmosphere often

resembles that which produces haze in summer; a slow infiltration of currents of different temperatures brings different laminæ into contact. A cold earth and a sky clear above the low clouds increase the intensity of such a fog, but are not necessary to its existence. A southerly wind is too warm to produce fog by itself unless it meets with a cold surface, and a northerly wind is too dry by itself to be reduced below the dew-point. When, however, two opposite currents, one of which is colder than the other, diffuse into each other slowly, as when the colder current over an extensive area sinks into the warmer current below it, a fog may be produced which is less thick than a radiation fog, but may continue with little change through several days and nights, and commonly declares its character by the height to which it extends and by its moisture. It deposits much more moisture on trees, etc., than most radiation fogs, and, though no visible mist or rain may fall, the ground under trees often becomes very wet. Thus precipitation of moisture is increased in forests. In cold climates or at high levels every exposed object accumulates ice. A wet or mixture fog disappears under cover, and is thinner in large towns than in the country, for the particles of which it is composed are almost pure water and evaporate when the air is a little raised in temperature. On mountains in Great Britain wet fogs are very common, and may occur with strong wind; moisture or ice is deposited on the windward side of all objects. Continuous damp mist may be produced in Great Britain by a northeast wind blowing beneath a damp southwest or south current, and such mists produce very disagreeable weather. In September and the first half of October, 1894, southern England was immersed for weeks in a mist so produced. The northeast wind was not of very distant origin, and, not being dry, its mixture with the very damp southerly current overlying it produced dense mist, cloud, and occasional rain.

Many fogs, such as those over rivers or valleys, and over the cold ocean current near the Bank of Newfoundland, are due partly to mixture and partly to radiation. The sea fog originates in the cooling of air by contact with the colder surface of water and by mixture with the cold air which lies near the water. At many coast places on a hot summer day a sea fog frequently comes up on a cool breeze which mixes with the warm air above it from the land. On the other hand, when a sheet of water is much warmer than the air above it, a thick mist or fog may be formed, which is largely condensed steam.

Fog is less common in summer in the interior of continents or of large islands than on the coast, but in winter, owing to the greater loss of heat by the surface of the earth than by the surface of the sea, fog is more common inland. In many countries in the temperate zone the stratum of cloud or fog does not lie often upon the ground, but at a height of hundreds or thousands of feet; the sky remains quiet and overcast for days and weeks together. The elevation of the cloud,

which would be fog on the ground, depends on the height at which the dew-point of the air is reached, or else on the height of the boundaries of a lower and upper current differing in temperature. The lower air is too dry to permit the condensation of vapor within its borders. A warmer and moister upper current condenses vapor by contact with the cold upper boundary of the lower air. The cloud canopy prevents excessive loss of heat from the surface of the earth.

A mist, in the usual meaning of the term, is the name given to very small rain, or to a cloud of which the globules are large enough to fall perceptibly. Near the surface of the earth it seldom, if ever, grows from radiation fog or from the haze of anticyclonic conditions, but very frequently is a result and direct growth from wet or mixture fogs. It may be considered as fine rain, which falls from a cloud undergoing cooling and consequent aggregation of particles. In hilly country near the sea, where the wind arrives after having blown over a large breadth of warm ocean, misty rain is very common.

At Kingairloch the number of dust particles was always very low in such weather, showing that the majority were being used up by the mist. The transparency of the air, or "visibility," so often preceding rain is due first to the paucity of dust particles brought by an ocean wind which is made purer than it otherwise would be by the clouds and rain of the area from which it blows; secondly, to the homogeneity of the air and the tendency to form large cloud globules or drops of rain when near saturation, the proportion of vapor to dust particles being high.

In quiet winter weather, a long-continued damp mist or else a very fine steady rain has, in the present writer's experience in England, preceded intense cold, and may be supposed with great probability to be caused by the gradual descent of very cold air upon the lower strata.

PARTICLES SUSPENDED IN THE AIR.

The atmosphere contains an immense number of substances suspended in it in the form of visible and invisible dust, but only a small proportion of these require attention as affecting human life. Deserts, dry and sandy tracts, and wind-swept plains yield a continual supply of fine motes of silica, aluminium silicate, calcium carbonate, calcium phosphate, etc. Volcanoes pour forth sand, fine mud, sulphur, sulphuric acid, silicon glass, etc., into the upper air, by which they are carried over all quarters of the globe. Meteors and small aerolites burn up as they daily pass through the high and rare atmosphere at heights from 30 to 200 or even 300 miles, and the products of their combustion, iron oxide, magnesia, silica, or other fine dust, fall impalpably toward the ground Clouds of unburnt carbon perpetually rise from towns, factories, steamships, and scattered houses; in manufacturing districts and towns particles of iron, steel, stone, and clay are abundant; so are fragments of vegetable tissue, cotton, hair, wool,

skin, and starch. Even coal gas, which shows no smoke in its combustion, fills the air where it is burnt with millions of particles in every cubic foot. The whole atmosphere is pervaded by particles of salt derived from the spray of the seashore and of ocean waves. In summer, pollen seeds, odors of earth, trees, flowers, and hay, and the spores of an immense variety of fungi float on every breeze. Most of these have no special interest, but some of the spores and pollen are capable of setting up great irritation in the human system, almost amounting to diseases. Hay fever is the result of the action of grass pollen on the breathing passages.

LIVING GERMS IN THE AIR.

Much more important are the living germs, the microbes, bacteria, fungi, and molds, which are found very unevenly distributed, and especially abundant at low levels in populous places and habitations. Miquel found in a cubic meter at Montsouris Observatory, near Paris, 85 of these organisms in spring, 105 in summer, 142 in autumn, and 49 in winter. On other occasions the numbers were 70, 92, 121, and 53, respectively.

In the Rue de Rivoli, in Paris, the number was about 5,500. In air collected at 2,000 to 4,000 meters high (about 6,300 to 13,600 feet) no bacterium or fungus spore was found. Pasteur exposed 20 flasks of clear broth in the open country of Arbois, 20 on the Lower Jura, and 20 near the Mer de Glace, at a height of over 6,000 feet. Of the Arbois flasks, 8 developed organisms; of the Jura, 5; and of the Mer de Glace, 1 only.

Miquel's experiments proved that microbes were much more abundant in the town than in the country. In rooms the number was eight times, and in hospitals twelve times the number in the open air. These experiments refer to hospitals in Paris only. In hot countries, after a prolonged period of dry hot weather, microbes diminish. In M. Miquel's view the places where there are most microbes are centers of infectious disease; the curves of mortality to a great extent correspond with the curves of the number of microbes and follow them after a short interval. In 1 gram of the dust of his laboratory he found 750,000 germs, and in that of a room in Paris 2,100,000. In the air of hospitals microbes of suppuration have been found. Devergie found an "immense amount" of organic matter in the air in the vicinity of a patient with hospital gangrene. Dr. Dundas Thompson found, in the air of a cholera ward, starch, woolen fibers, epithelium, fungi, or spores of fungi, and vibriones. Scaly and small round epithelia are found in most rooms, and in large quantity in hospitals. The dust of a hospital ward at St. Louis contained 36 to 46 per cent of organic matter, largely epithelium cells. Parkes similarly detected large quantities of epithelium in the air of barracks and hospitals. In 1 gram of dried earth Miquel found 800,000 to 1,000,000 microbes. Recent research shows the number is

especially great on the surface near dwellings, and rapidly decreases with depth, so that at 1 meter down there are few. Ninety per cent of these soil microbes are bacteria, chiefly in the form of spores. It is easy to understand how these may be carried into the air, especially in dry weather, as dust by wind and by evaporative forces.

It has been calculated that in a town like London or Manchester, a man breathes in during ten hours 37,500,000 spores and germs.

In Berlin an investigator found 3 colonies of bacteria and 16 molds in 25 liters from an open square, and 37 colonies of bacteria and 33 molds from a schoolroom just vacated. Professor Tyndall exposed for a short time 27 flasks containing an infusion of turnip, etc., to air on a ledge of rock above the Aletsch glacier in Switzerland, an altitude over 8,000 feet, and then carried them to a kitchen stove with a temperature of 50° to 90° F. In the same way 23 flasks were exposed to the air of a hayloft near the same altitude and placed with the others in the stove, due precautions being taken in all cases to prevent the kitchen air from contaminating the flasks. Of the 27 flasks opened in free air not one showed a sign of organic life; of the 23 opened in the hayloft, 21 were invaded. Many other experiments in London and elsewhere convinced him that the air of an ordinary room swarms with germs of life, and that if infusions of flesh, fish, or vegetable be exposed even for a short time to the dusty air they become turbid and putrid within a few days. Exposed for months to air "optically pure," that is, deprived of dust, they remain clear and sweet for months, in fact, do not putrefy at all. Some of the germs or spores in the air have a very remarkable resisting power and will germinate after several hours' boiling; others are killed in five minutes. The spores of bacillus subtilis, which is common in hay or in the air of haylofts, is not killed by prolonged boiling. But bacilli themselves, which are soft and unprotected, are killed by boiling water within a few minutes. The small size of the germs and bacilli may be to some degree realized when we note that in Tyndall's estimation the number in a single drop of turbid infusion is probably 500,000,000 "many times multiplied." The evaporation of such a drop would then conceivably permit the launch into the atmosphere of more than one thousand million organisms. The natural processes of decay in most places on the surface of the earth must be incessantly nourishing immense numbers of microbes in very great variety, and wherever drying or heating takes place quantities of colonies of all sorts which can flourish in daylight must be raised into the air and widely disseminated.

Percy Frankland counted the number of microbes falling on a square foot in one minute in several situations, with the following result:

Roof of Science Schools, Kensington, March	851
Roof of Science Schools, Kensington, when the wind was stronger	1,302
Roof of Science Schools, Kensington, after rain	60–66
Roof of Science Schools, Kensington, during thick fog	26–32
Burlington House, during Conversazione	318
Burlington House, on following morning	109

Natural History Museum, Entrance Hall, Whitmonday	1,755
Hospital for Consumption, morning	18
Hospital for Consumption, afternoon	66
Railway compartment, open window, 4 persons	395
Railway compartment, window 4 inches open, 10 persons	3,120

In experiments made with the object of finding the number of microbes in a certain volume of air, he found at a height of 300 feet on Norwich Cathedral, only 7 in 2 gallons; on the gravel near the cathedral, 18; at the top of Primrose Hill, 9; at the foot, 24.

Dr. Fischer found, in experiments made at sea, that at 120 miles from land, in eleven out of twelve experiments, the air was quite free from germs; that at 90 miles from land, in seven cases out of twelve, there were germs, but very few. Practically it appears that at 120 sea miles distant from land the air is pure and free from microorganic life.

Angus Smith roughly calculated the amount of organic matter, living and dead, to weigh, in pure air on high ground, 1 grain in 209,000 cubic feet; in a bedroom, 1 grain in 64,000 cubic feet; in a closely packed railway carriage, 1 grain in 8,000 cubic feet.

He obtained some curious results by shaking up air in different places with water. The air of a cowhouse gave an effect only produced by fifty to one hundred times the quantity of good air, and contained a mass of débris, hairs, etc. The air behind houses in streets was worse than in front of them.

Moisture collected from the air above marshes has been found by Italian observers to contain multitudes of seeds of algæ and of microscopic infusoria. The condensed dew exhibits a surprising quantity of spores and sporangia.

Other observers agree in noting decaying organic matter in abundance, vaporous and solid, together with living minute forms of animal and vegetable life, floating in the air; these consist of algæ, diatoms, fungi, bacteria, and other microorganisms.

The subtilis, or hay bacillus, is always present in the open air, but the bacilli generally keep to low levels and do not extend so high as the mold fungi.

Cunningham, at Calcutta, found spores and other cells constantly present in the free air, usually in considerable numbers. The majority were living, capable of growth, and seemed independent of moisture and direction of wind.

Mr. Greenleaf Tucker found that outside the City Hospital of Boston 10 liters of air contained on an average 10 colonies of bacteria, 7 of molds, in November; 13 of bacteria and 3 of molds in January. The number of bacteria was less on rainy days. The hospital itself contained few bacteria, owing to constant care and cleanliness, but the number was much increased after sweeping and bedmaking.

Carnelley found in clean one-roomed houses 180 bacteria per 10 liters; in dirty houses, 410; in very dirty, 930; in schools, from 300 to 1,250, according to ventilation; in the Royal Infirmary, Dundee, 10 to 20.

The greater part of the dust of clean habitations, consisting of motes derived from mineral, vegetable, and animal substances, has little apparent effect upon health. But it certainly tends to reduce vitality by some small amount, and gives extra work to the breathing organs. Consequently, to invalids and delicate persons it is important to reduce this dust by all reasonable means. A beam of strong light, sunlight or the electric lamp, shows the air of most inhabited rooms to be so crowded with dust as to be almost opaque to vision. Aitken found 41,000,000 particles in the cubic inch in a room where gas was burning. Rooms with polished wooden floors, painted hard plaster, glazed paper, or wood-paneled walls, and not containing fluffy fabrics, evolve much less dust. They are more healthy not only on this account, but chiefly because they provide much less pabulum and protection for the growth of noxious microorganisms.

De Chaumont found in the air at Paddington and in University College Hospital particles composed of the epidermis of hay, of pine wood, linen, cotton, epithelium, charred vegetables, and minerals.

Tichborne, of Dublin, found in a street 45.2 per cent of organic matter, and at the top of a pillar 29.7 per cent. Most of it was finely ground manure.

The spores and mycelium of *Achorion schonleinii* and of *Tricophyton tonsurans* have been found in the air of a hospital for diseases of the skin.

The surface of the ground in streets, squares, courts, and gardens, and the sweepings of dwellings and stables, contain swarms of the germs of the bacillus of tetanus, a disease fatal to man. These chiefly infest the droppings of various domestic animals, and may be carried through the air to wounds; commonly they infect by contagion and not through the air. Drying, light, and putrefying matter do not kill the bacillus, nor does a temperature of 80° to 90° C. Tetanus has caused great mortality among soldiers who have lain wounded at night on the field of battle, probably owing to the lifting of the bacillus by emanations from the ground and its deposit on open wounds.

SEWER AIR.

Sewer air contains molds, fungi, bacteria, and animal and vegetable débris. The microbes do not exceed about 6 per liter in a good sewage system. In ordinary drains, however, they are much more numerous, and are borne into the interior of houses in company with highly poisonous gases. The gases of sewers are sulphuretted hydrogen, ammonium sulphide, carbon bisulphide, a very little marsh gas, compound ammonias, with traces of ptomaines and leucomaines.

AIR OF MINES.

The air of mines contains only a few molds, fungi, and bacteria.

GROUND AIR.

Ground air contains microorganisms in abundance, according to locality and conditions, but has hitherto been little examined. It contains an enormous quantity of carbon dioxide, which is at its maximum from July to November. The foul air of cesspools is sometimes drawn into houses through 20 feet of earth.

When organic substances decompose in the air, they are first attacked by molds, then by bacteria. These last cause odorous gases to be emitted, which are oxidized by the air. If the air has access to the substances, aerobic organisms multiply; if only slight access, as in masses of filth in a drain, anaerobic multiply, such as those of putrefaction, of tetanus, and of malignant œdema.

ORGANISMS, ETC., IN THE OPEN AIR.

The open air in populous places contains much dust of suspended matter and many living organisms. Débris from wool, silk, fibers, hair, feather particles, dried epithelial cells, epidermic scales from the skin, pus cells, pyogenic microorganisms, fragments of insects, and fecal particles are among the former, and living minute ova or infusoria, minute amœbiform organisms, etc., which may even *grow* in the atmosphere, are among the latter. All these are of animal origin. Of vegetable origin are the following: Soot, fibers, hairs, cells, starch, straw in powder, spores of molds, fungi, diatoms, and bacteria; living pollen seeds, spores of fungi, molds, diatoms (which may live and grow in the atmosphere), and, rarely, mycelium of fungus, algæ, bacteria, and their spores. In woods in September basidiospores are abundant. Of mineral matter, sodium chloride, or common salt, is always present.

MICROORGANISMS IN ROOMS.

Many living microbes float in the air of all dwelling houses, but in rooms which are old, overcrowded, and dirty, the numbers are very much higher. These come for the most part from the sides and floor, and not from persons, but they are much more numerous when the dust is disturbed than when the room has been quiet for a short time. In schools, large numbers of microbes find a nidus under and between the boards of the floor if these are not close-joined. Bacteria chiefly abound, but many mold and yeast fungi are also present. The latter belong more to the external air, the bacteria to the internal air, and since the bacteria are the heaviest, the air of a room which is left quiet contains a preponderance of molds and yeasts. Pathogenic or disease germs are nourished to a great extent by the floors and walls of rooms, and for this reason the material should be smooth and easily washed. In schools and places which are frequently crowded, cleansing should be frequent, and no opportunity of extensive growth of bacterial colonies should be tolerated. An inquiry into the relative impurity of air in differently constructed buildings would be useful.

The clothes of scholars should be clean and washable, and there should be no crowding together in the class rooms.

SEWER AIR.

Sewer air in sewers of good construction, in good order, and at ordinary temperatures, contains very few living organisms discoverable by the usual methods. Microbes are not easily given off from sewage unless it be in a state of fermentation, and those which escape soon attach themselves to the wet surfaces of the sewer and drains. Yet there may be microorganisms which are not capable of cultivation and observation by means hitherto tried, but which are the agents concerned in the putrefactive and disease-causing changes set up in organic substances exposed to sewer air.

Moreover, the presence of a very few pathogenic microbes may be sufficient, when inhaled with the noxious gases in which they float, to set up typhoid and other dangerous disorders.

It is well to guard against the assumption that negative evidence proves anything in these cases. The bacilli or organisms of smallpox, measles, whooping cough, malaria, etc., are either undiscovered or very difficult to see and to identify. Drinking water which may be clear, bright, and pronounced by microscopic analysis to be pure and excellent, may poison by the invisible germs of typhoid which it contains. Analysis of water and of air is sometimes a less trustworthy arbiter than the senses, or than knowledge of suspicious circumstances.

Often a family lives in a badly drained house for a long time without suffering anything worse than headaches, diarrhea, sore throat, or loss of appetite. These ailments may be due either to habitual inhalation of the poisonous gases, or to the gases joined with slightly virulent microbes. Depressed vitality gives a strong presumption, if other conditions are wholesome, that drain air enters the house.

When drains and sewers are out of order, or fermentation is going on, or where there is old sediment, it is probable that a large number of microbes of a disease-producing kind are evolved and carried by the gases and air into houses. The process of decomposition and fermentation sets free small bubbles of gas in the liquid and on the wet surface, and these bubbles in bursting scatter a number of small particles into the air. The force with which liquid particles are scattered upward may be observed in the breaking of minute bubbles such as those which rise to the surface of a glass of effervescing water. Experiments on various drying and putrefying liquids could hardly fail to furnish interesting results. There seems to be great probability that bacteria or their spores are thrown in quantities into the air from viscous putrefying or fermenting liquids. Certainly a fermenting brewer's vat scatters multitudes of yeast germs into the air, and the case seems strictly comparable.

VAPOR AND ORGANIC MATTER FROM LIVING BODIES.

The lungs and skin together give off about 30 ounces of vapor in the day, or about 550 grains an hour, enough to saturate about 90 cubic feet of air at 63° F. Estimates naturally differ as to average amounts, but Professor Foster states that the water given off from the lungs in the day is about 1.5 pounds and from the skin 2.5 pounds. Vapor in a room ought not to exceed 4.7 grains per cubic foot at 63° F., or 5 grains at 65°. This vapor is practically not pure, for it is associated with minute portions of organic gases and solids, and condenses with them upon the walls, ceiling, and furniture, whence it emerges again with organic dust when these are warmer than the air of the room.

Organic matter is given off from the lungs and skin, of which neither the exact amount nor the composition has been hitherto ascertained. The quantity is certainly very small. but of its importance there can be no doubt. It darkens sulphuric acid, decolorizes permanganate of potash, and makes pure water offensive when drawn through it. Collected from the air by condensation of vapor in a hospital, it is found to blacken platinum and to yield ammonia; it is therefore nitrogenous and oxidizable. It has a very fetid smell and is only slowly oxidized by fresh air. It is molecular or particulate; it contains epithelium and fatty matter from the mouth and pharynx, sometimes effluvia from the stomach. Damp walls, moist paper, wool, and feathers are capable of largely attracting or absorbing it. Experiment shows that it bears a nearly constant proportion to the carbon dioxide in inhabited rooms, so that this gas is conveniently taken as an indicator of the amount of the organic matter in the air. Since this organic matter has been proved to be highly poisonous,[1] even apart from carbon dioxide and vapor, we may safely infer that much of the mischief resulting from the inspiration of rebreathed air is due to the special poisons exhaled from the body, their fatal effect being accelerated by the depression of vitality caused by the gaseous products of respiration and by the want of oxygen. Air thus organically vitiated and confined in places long inhabited, which are subject to continual condensation on their surfaces, without proper cleansing, appears to play a very large part in the propagation of disease in man and animals.

The quantity of particulate organic matter given off has been estimated at 30 to 40 grains for each adult. This is certainly sufficient for the nutriment and sustenance of a very large number of micro-organisms, which may grow, in the presence of moisture, upon it and upon other dust deposited upon the walls, floor, and ceiling. Water through which breath has been passed, and kept at rather a high temperature, gives off an unpleasant smell, and putrefaction is set up.[2] It does not appear to be definitely ascertained whether the breath and

[1] Dr. A. Ransome and others.

[2] Carpenter; Douglas Galton.

skin actually and normally emit in good health living microorganisms, either pathogenic or harmless, but the probability is considerable when we remember that the mouth and air passages are inhabited by various species, and that warm evaporating surfaces exercise a repulsive force on minute particles. Foster states that the aqueous product from the breath is very apt to putrefy rapidly, owing to the presence of micro-organisms. It is not generally assumed, however, that living microbes are exhaled to an appreciable extent. The subject is an important one and demands inquiry, but the ultra microscopic minuteness of the germs may defeat direct observation. As to the frequent emission of a deadly particulate poison, however, no doubt whatever can exist.[1] It is a dangerous and pernicious element in all aggregations, and, combined with carbon dioxide, produces, when in moderate quantity, depression, headache, sickness, and other ailments; when in large quantity, as in the Black Hole of Calcutta, and in various prisons of which there is record, rapid death in the majority and fever in the survivors. Its action upon the development of living germs when deposited upon outside objects has not been ascertained. Probably it may be favorable to some and unfavorable to others. Some of the most deadly human and animal diseases certainly are capable of virulent growth in their presence, and of passing more easily in a potent condition through air in which they are abnormally concentrated.

ORGANIC EMANATIONS FROM THE SICK.

Hospitals, when not well ventilated, contain a very large quantity of organic matter floating in the air and deposited on walls and floors. This gives rise, in the most impure air, to hospital gangrene and erysipelas, increases the severity of many diseases, and prolongs convalescence. Gangrene having once appeared, is very difficult to get rid of. Thorough ventilation and hygiene of the building where the sick are received and treated prevents these evils from arising.

ORGANIC EMANATIONS FROM THE SKIN.

Sweat contains salt, lactate, butyrate, and acetate of ammonium; calcic phosphate, ferric oxide, volatile fatty acids, e. g., sometimes valerianic and caproic acid, and sometimes leucin. Perspiration gives off into the air a large quantity of vapor, about 2 pounds in the twenty-four hours and a little over 1 per cent of this quantity of solid organic matter. Fatty acids, inorganic salts, neutral salts, ammonia, and particles of epidermis are constantly passing from the skin into the air. In the sick the matter emanating from the skin is often largely increased and is very offensive.

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[1] Some recent experiments of Smith and Haldane seem to show that carbon dioxide is the only element of mischief, but the conditions of ordinary life are so various and so difficult to imitate in experimental investigation that the inquiry needs to be widely extended.

The poisonous matter emanating from the skin of healthy people and animals, if thrown back upon the body by accidental or artificial means, causes death in a short time, not only in the case of rebreathing, but in cases where the pores of the skin are stopped, as by gold leaf or plaster of paris. Sheep have died in large numbers after being dipped in a resinous compound. The poison returned upon the body by the stoppage of the pores by finely divided soot may be a cause of the excess of cancer in chimney sweeps. Dirty bedding used after having been rolled up for two months has given fever.

The relation of the organic matter of respiration to disease can not be doubted, and, indeed, it seems probable that much of the mortality of infant and adult life may be due to the rebreathing of poison excreted by breath and skin. These are known to be, mediately or even sometimes directly, a great cause of consumption, pneumonia, and bronchitis. The recent experiments on the development of typhoid fever by the respiration of sewer gas lead naturally to the inference that other poisons besides that of sewer gas may play a very important part in laying the system open to the attack of disease germs either from within or from without the body. The chemistry of the expired breath deserves full investigation in many different cases and circumstances.

Gaseous emanations from sewers, drains, cesspools, and foul refuse cause diarrhea, vomiting, and prostration, or a low state of health. Children are more susceptible than adults, and when they breathe the gases largely diluted may suffer from languor, sore throat, and diarrhea. These results may be due simply to chemical or inorganic poisoning. Where the specific organism is present, typhoid, epidermic diarrhea, or diphtheria may result. Well-managed sewage farms do not seem to cause illness in their neighborhood. Sodden and neglected farmyards, on the other hand, are both common and pernicious. A great deal of illness, affecting both man and animals, arises from them. Thus "circulation," as in sewage farms, versus "stagnation," as in farmyards, shows its great superiority, even where other circumstances are apparently adverse.

The air close to certain crowded burial grounds has had a very bad effect on people living near them: it has greatly aggravated any disease from which they suffered.

The effluvia from decomposing corpses produces dysentery, diarrhea, or a low fever, and in some circumstances diseases of a more severe character.

SULPHURIC AND HYDROCHLORIC ACIDS.

Sulphuric and hydrochloric acids exist to a small amount in the atmosphere, but are not easily discovered except when brought down to the ground dissolved in mist or rain. Hydrochloric acid is one of the most soluble gases known, water at ordinary temperature absorbing five hundred times its volume. At Rothamsted, about 23 miles from London, the sulphates in rain were 0.0027 in the summer and 0.0032 in the

winter; the chlorides were much less in summer than in winter. The average of sulphates in a certain period of thirteen months was 0.004, of chlorides 0.0033. Seven samples collected near Horsham, in Sussex, gave sulphates 0.0048, chlorides 0.0041. A sample collected on Dartmoor during a gale from the southwest gave the following results: Sulphates 0.0005, chlorides 0.0087. Proximity to the sea evidently increases the chlorides and reduces the sulphates. At St. Bartholomew's Hospital, in central London, the sulphates were 0.0388, the chlorides 0.0179, and the amounts were greater in summer than in winter. The quantities of these impurities in the air of a large town are much above the average of the country. The rain does not give acid reaction, but wherever it is contaminated with soot it becomes distinctly acid after a few hours. Soot, then, being acid and becoming moistened by rain, must play an important part in the corrosion of buildings and other materials on which it has been deposited. Experiments were made by Dr. Russell by means of a conical vessel filled with ice, to ascertain the amounts of impurities condensed from air in London. The results were remarkable: sulphates 0.1344, chlorides 0.0506, ammonia 0.006; and in fogs the amounts were 0.2480 sulphates, 0.1215 chlorides.

ARSENIOUS ACID IN RAIN.

A gallon of rain in the city of London has been found to contain 0.00021 grain of arsenious acid.

AMMONIA IN THE AIR.

Ammonia is always present in the air in minute traces, either free or combined. It is a chemical compound of 14 parts by weight of nitrogen and 3 of hydrogen, and arises from the decomposition of organic matter. It is lighter than air in the proportion of 8.5 to 11.47. Although the quantity rarely exceeds 3½ parts in 10,000,000 of air, this is sufficient to be of very high importance to the growth of vegetation, for the gas is soluble to quite an extraordinary amount in water, and is thus continually being brought down from the atmosphere in rain and dew. Brandes found, by evaporation of rain, in each million kilograms from 8 (May) to 65 (January) kilograms of residue, of which ammonia salts formed a considerable portion.[1] Rain, according to Boussingault, contains about three-fourths of a milligram of ammonia per liter, equal to 7 kilograms per hectare per annum. Dew contains about 6 milligrams, equal to about 29 kilograms per hectare per annum; fog, about 50 milligrams, and in Paris, 138 milligrams. Water dissolves from 700 to 1,000 times its volume of ammonia, according to the temperature. Representing the quantity of ammonia in rain at Valentia, in Western Ireland, by 1, the quantity inland in England was 5.94, at Glasgow 50.55. The albuminoid ammonia was: Valentia 1, Manchester 7.38, London 6.23.

[1] Pierre.

In summer the amount in the air is highest, in winter lowest. In large coal-burning towns it is considerably more abundant than in the country, and is deposited with carbonaceous, sulphurous, and organic matter on exposed surfaces during the prevalence of fogs. Foggy air in these towns contains an excess of sulphates and chlorides, but a still greater excess of organic matter and ammonia salts, often double the normal. The ammonia contained in the deposit on glass roofs in Chelsea and Kew after fogs was respectively 1.4 and 1.1 per cent. The processes of combustion, both in manufactories and in domestic fires, of coal and of coal gas, give rise to ammonia.

Only traces of ammonia are evolved from the lungs, and a little from the skin and in perspiration.

The smell of ammonia is distinguishable in most stables, but where strong we may be sure that ventilation is deficient. Main streets, especially where wooden pavements are used, often smell offensively of ammonia; on still, dry days the ammoniacal dust is thick in the air, and in windy weather is blown about in clouds. Analysis has shown that 95 per cent of the dust from wooden pavements in main London thoroughfares, consists of horse dung. This is breathed into the lungs and often produces sore eyes and sore throat. Such pavements should either be kept scrupulously clean throughout the day or be properly watered, in order to reduce harmful dust, and an occasional coating of tar would not only prevent the emanation of noxious matter, but would preserve the wood.

Ammonia, being everywhere present in the air and extremely soluble in water, may truly be said to be attached to all exposed surfaces where moisture is also present; in the neighborhood of human habitations and decaying animals or vegetable matter it has been found on all objects; in a room, if a perfectly clean glass be suspended, traces of it appear after an hour and a half. Evolved in small quantities from the skin and lungs, it must be deposited with condensed vapors on the walls, ceilings, and floors of dwelling houses.

NITRIC ACID IN THE AIR.

Nitric acid also pervades the air in minute quantity, and, with ammonia, plays a great part in the development of plants. It results partly from the combination of nitrogen and oxygen in the atmosphere caused by thunder storms and partly by the oxidation in loamy soil of the ammonia of decomposing organic matter. It seems probable that many forms of bacteria or molds may be favored in their growth by the presence, with moisture, of these two nitrogenous substances. Within human habitations, cow sheds, etc., we must regard the walls, and all surfaces as covered with a thin top-dressing of moist organic dust and ammonia. Within the soil ammonia appears to be oxidized to nitrites by one set of microorganisms, while another set oxidizes nitrites to nitrates. To the latter the presence of ammonia is a hindrance.

LOCAL GASEOUS IMPURITIES—SULPHURETED HYDROGEN—SEWER AND DRAIN AIR.

When certain animal and vegetable matter undergoes decay, the small quantity of sulphur which it contains combines with hydrogen and forms the gas, sulphureted hydrogen, which, even in mere traces, is very offensive to the sense of smell. It also forms some offensive organic sulphides. The sulphureted hydrogen gas set free often bears with it germs of disease, so that it has been treated as a danger signal. Drain or sewer air, however, does not always contain the gas in appreciable amount, when dangerous germs are being given off, and the faint smell of an old filth deposit may exceed in morbific effects the unpleasant odor of fresh putrefactive processes. Nor does sewer air, even if it be poisonous, often contain virulent germs of disease. Dogs and horses are rapidly prostrated by 1.25 to 4 volumes of sulphureted hydrogen per 1,000 of air, but men can breathe a larger quantity. In large doses, nausea, headache, convulsions; in small doses, low febrile symptoms follow its inhalation. The frequent inhalation of small doses produces chronic poisoning: 1 per cent is at once destructive of life.

The air over some of the most pestilential marshes in Italy contains an unusually large quantity of the gas. In mines it produces convulsive, narcotic, and tetanic symptoms.

SULPHUROUS ACID.

Sulphurous acid in the air of cotton and worsted manufactories apparently tends to produce bronchitis and anæmia. It destroys vegetation in the neighborhood of copper works.

CARBURETED HYDROGEN.

Carbureted hydrogen, breathed in small quantities, as in the air of some mines, does not seem to cause ill effects, and experiment has shown that for a short time it can be breathed in the proportion of one volume to four of air.

HYDROCHLORIC ACID.

Hydrochloric acid vapor is very irritating to the lungs. In some processes of making steel this gas, with sulphurous and nitrous acids and chlorine, cause bronchitis, pneumonia, destruction of lung tissue, and eye diseases among the workers. It destroys vegetation for a long distance when given off in large quantities from manufactories.

CARBON BISULPHIDE.

Carbon bisulphide vapor, given off in vulcanized india-rubber factories, produces, in those exposed to it, headache, giddiness, pains in the limbs, nervous depression or excitement, and complete loss of appetite.

Carbon monoxide is a very poisonous gas arising from the consumption of coal, coke, coal gas, and especially charcoal. Less than 0.5 per cent is fatal to animals. Fatal consequences from the use of charcoal stoves where ventilation is defective are common in some countries.

Carbonic oxide is given off by iron works, brick fields, copper furnaces, and cement works. It is dangerously present in the cheap illuminating gas known as "water gas."

ORGANIC VAPORS.

Organic vapors of various composition are given off by marshes, wet forest ground, "made soil," soil containing organic matter under warm sand, and by many manufactories for the conversion of animal refuse, etc. The effluvia from tanneries, glue and soap works, slaughterhouses, pigstyes, etc., are apt to lower the health of people living near them and to aggravate disease.

SOLID ARTIFICIAL IMPURITIES.

Many severe forms of disease, especially of the respiratory organs, are caused by the dust inhaled in various trades and occupations. These are generally proportionate to the sharpness and angularity of the dust and its quantity. Coal dust is among the least harmful. Among lead miners, bronchitis and lead poisoning; in copper mines, gastric disorders; in pottery works, in stone cutting, steel grinding, in flax and cotton factories, in shoddy works, and in metal polishing, lung diseases are common, and the death rate is high.

Thus the comparative mortality of file makers was 300 compared with 108, that of gardeners; of earthenware makers 314, compared with 139, that of grocers; of cutlers and scissors makers 229, compared with 129, that of paper makers. The dust of soft woods and of flour seems to have little bad effect.

As regards phthisis and lung diseases the figures of several trades are as follows, when compared with fishermen, 100: Carpenters, 170; bakers, 201; cotton workers, 274; file makers, 396; stone and slate quarrymen, 294; pottery makers, 565; northern coal miners, 166. The injuriousness of the dust in cotton mills is increased by the use of mineral substances for sizing. The mortality of cutlers, etc., from these diseases is almost as great as that of fishermen from all causes put together, including accidents. The comparative exemption of colliers in well-ventilated coal mines deserves investigation, for there would appear to be some ground for the supposition that it may be owing to an inhibitive action of this particular dust upon the development of tuberculosis; on the other hand, it may be simply through living in fairly good air of an even temperature, where the specific germs of phthisis are few or absent. The homes of the men are generally comfortable, and much larger fires are kept up than in the south, so that their rooms are dry and well ventilated.

Part II.—Climate, Air, and Health.

MALARIOUS AND INFECTIOUS DISEASES: THEIR CONNECTION WITH AND DESTRUCTION BY THE ATMOSPHERE—THE INFLUENCE OF CLIMATE ON NATIONAL HEALTH.

The spreading, infectious, or epidemic diseases in the animal world and in mankind depend to a very great extent upon aerial influences.[1] Microscopic fungi or microbes, the prime causes of these disorders, are sensitive to dryness, moisture, heat, cold, and sunlight, and a study of their relations to the atmosphere has led and will lead to results of the very highest importance to human welfare. Many of them reach the living body, upon which they lodge, through the air; many are partly nourished outside the body by the gases and moisture which the air brings to the seat of their growth. But as a whole the pure atmosphere works energetically and unceasingly for their destruction; dry air and sunlight deprive most species of disease organisms of their vitality. This great generalization may best be appreciated by a brief review of the principal endemic, epidemic, and pandemic maladies to which the human race is subject, dealing especially with the manner in which they are developed, restrained, diffused, or annihilated by the qualities of the air.

Microbes have been divided into two main classes, aerobic and anaerobic, the first growing best in the presence of air and the second growing best in substances and in positions to which free air has no access.

Some of the first class, such as the hay bacillus (subtilis), grow best only with a copious supply of air; some grow better when the air supply is not large than when free air is admitted; some of the second class can grow in the absence of free air, but thrive more when some air is admitted; and others, which are fully anaerobic, grow only when free air or oxygen is shut off. Examples of these last are the bacillus of symptomatic anthrax, of tetanus, and of the malignant œdema of Koch.

A large class of bacilli or bacteria are killed by dry air, by light, by artificial heat, and by prolonged intense cold, but are capable, when adverse influences act upon them, as by deficiency or inappropriateness of the nutritive medium, of forming spores, minute germs which are scattered abroad in a condition of far stronger defense, and capable of resisting for some considerable time prolonged exposure to sunlight and even to boiling water, to drying, to various antiseptic chemicals, and to any possible natural cold. The spore-bearing faculty belongs to a variety of species of bacilli, both pathogenic and harmless.

[1] "The atmosphere is the most universal medium or vehicle" of their poisons to the breathing organs and intestines. (Professor Corfield, medical officer of St. George's, Hanover Square, London.)

Spore formation takes place at temperatures between 16° and 45° C., and these are in general the extreme limits. Bacilli which do not form spores—for instance, those of typhoid fever, glanders, and fowl cholera—are easily killed outside the body by a number of natural and artificial agencies. Among these agencies the most efficacious are drying, exposure to dry air and oxygen, high temperature, sunlight, the presence of other species of microbes, the poisons evolved by themselves or by other species, cold weather, exhaustion of their appropriate nutriment, and various inimical substances which inhibit growth or actually kill. In the very fatal diseases of cattle known as anthrax, and when transferred to mankind, as wool sorter's disease, the bacilli which infect the blood of the dead animal are killed by mere drying, without exposure to air; but if the blood be for some little time exposed to the air, spores are formed which may remain upon the pasture, or upon wool, or hides, or elsewhere, and infect fresh cattle or human beings at some distant date. The putrefactive process in the carcass also kills the bacilli, but will not kill the spores if these are allowed to be formed.

Anthrax is known to be in many cases communicated through the air from one animal to another or to man, and among wool sorters, butchers, and others enters the body through a wound, or by the lungs, or by the alimentary canal.

Spore formation is generally favored by a copious supply of oxygen. It is a process by which the degeneration and destruction which takes place in a colony of nonspore-bearing bacilli is prevented, and by which the seeds are set adrift, to be planted and grow again into bacilli in more favorable surroundings.

The process of growth from a spore into a bacillus has been experimentally observed in favorable conditions to be completed in periods varying from half an hour to two hours. The bacillus introduced into an appropriate medium multiplies by fission at an enormous rate, so that, for instance, 248 microbes of the pathogenic species *Staphylococcus pyogenes aureus* in a cubic centimeter increased to 20,000,000 in twenty-four hours, and 20,000 bacilli of fowl cholera multiplied in the blood of a rabbit to about 1,200,000,000 in twenty hours.

Microbes vary greatly in size not only between classes and species, but between individuals, according to the medium and circumstances of growth. Ordinary dimensions lie between about 0.5 and 5 micromillimeters in length and 0.1 to 0.5 in breadth. The spores are in many cases much smaller. Clearly, an organic living dust of less than one thousandth of a millimeter in diameter is capable of existing in great numbers on very small areas, even on small, almost invisible, dust, and of being wafted long distances by gentle aerial movements without sinking. In perfectly still air inclosed in a box in the laboratory Tyndall found that all visible dust sank within three days, and nutrient media then exposed were unaffected by bacterial growths, so that

the microorganisms originally present must have settled down. But in nature not only is such a calm unknown, but processes are continually taking place which launch fresh organisms into the atmosphere. Moreover, there is good reason to suppose that several disease microbes or their spores are still lighter than those which have been subject to similar experiments. The influenza microbe is extremely light. Its length has been given at $\frac{1}{50000}$ and its breadth at $\frac{1}{250000}$ of an inch. Disease microorganisms have in the laboratory passed from room to room through the air, and accidentally infected animals inoculated with other kinds. Light dust falls at so slow a rate through the viscous air that even in a room the downward motion is scarcely perceptible; yet in a few hours all the grosser particles are deposited if drafts, movement, and shaking of the room are prevented. Most pathogenic microbes are carried down with this dust or sink of their own gravity, and soon subside, but in ordinary conditions there is too much disturbance to permit effective purification by subsidence. The light dust of the volcano Krakatoa, which was visible as a haze, took a year to fall even out of the rare upper strata, and many disease microbes are equally small, and fall still more slowly through the dense strata near the ground. Particles of smoke may perhaps be compared with the spores of bacteria, and tobacco smoke not only floats long in the air of a room, but passes through passages and through chinks into rooms above and below.

Among animal diseases of an intensely infectious character and disastrous to agriculture, cattle plague, pleuro-pneumonia, and foot-and-mouth diseases are perhaps foremost. Two, at least, of these are communicated not only by infected articles, but by transmission through air for a short distance of particles derived from an actual or previous case. These diseases, or some of them, have formerly been widely held to come from some unusual epidemic constitution of the air, but they are now thoroughly proved to be preventable by the admission of plenty of external air and rigid precautions against contact or proximity of infected articles. They are frequently spread by attendants passing from one herd to another without complete systematic disinfection; frequently also by imperfectly disinfected sheds. No animal plague has been proved to be capable of passing effectually through a long stretch of atmosphere, and the free atmosphere in all cases tends to diffuse and destroy the poison. There is reason to regard certain low alluvial lands and swamps as the original breeding grounds of the saprophytic microbes which cause some of the worst animal plagues, for these plagues have followed immediately the subsidence of floods and the drying up of marshes. Since the neighborhood of these places is not exempt, the organisms concerned must be capable of transport in a potent state for a short distance by moist air. The filthy condition and foul, unventilated air in which cattle are kept have also been shown to be the cause of their gravest maladies. Tuberculosis in

animals depends to a very high degree upon the absence of proper ventilation and upon proximity to each other. In the open air and wild life it does not seem to occur. It has been well ascertained that the microbes of cattle plague may cling so persistently to infected places that whitewashing, scraping, and ordinary disinfection may be insufficient. Similarly, tuberculosis of cattle occurs again and again in particular stalls, showing that the infective matter remains in a virulent condition on the walls, floor, or ceiling, and probably infects not only by contact, but through air. The breath of the animal condensed on the walls would no doubt form pabulum for the increase of any remnants of a former multitude which might light upon them or emerge from the pores of the material. In France, epizootics greatly increased after the introduction of railways, owing to emanations from and contact with incompletely disinfected cattle trucks, yards, sheds, etc., and the diffusion of infectious cases by increased movement.

INSUFFLATION OF ANTHRAX, ETC.

The inbreathing of the bacilli of cowpox, anthrax, clavelee, and suppuration is sufficient to give each of these diseases to sheep and cattle. But there is no evidence to show that any animal plague is transmissible through any long distances of air or by the general atmosphere: on the contrary, animals are in thousands of instances kept within a mile or less of others which are stricken, and with due precautions remain well.

TUBERCULOSIS.

Many of the epizootic diseases which occur in animals may be transmitted to men, but they often occur in a modified form and are either more or less severe. Some may have been originally human maladies. Fifteen at least are said to be thus interchangeable. The most important, widespread, and fatal of these is consumption, phthisis, or tuberculosis. The bacillus tuberculosis kills about 1 in 8 of the population of Great Britain and America, and about an equal proportion, one-seventh, according to a very high authority (Hirsch) of the people of the majority of other civilized countries. It is the greatest and most constantly present plague of man. It has been considered ineradicable, constitutional, hereditary, and attributed by many authorities to some vice in the atmosphere. Now, we know that it is a nationally self-inflicted, unnecessary, and preventable pestilence, of which the great and certain prophylactic is pure air in plenty; no foul air, foul dwellings, and overcrowding. Overcrowding, the rebreathing of expired air, dirty, dusty dwellings, moist or organically polluted walls, floors, ceilings, and furniture, and the careless habit of spitting account for a very large part, perhaps the majority, of cases of consumption. The breath in fetid air, the emanations from cultures of the bacillus on the walls, curtains, carpets, etc., and, most potently, the dust of the dried

sputum itself of consumptives, may infect healthy persons, but mostly those who have some tissue delicacy or predisposition. But another very common cause, especially in the largely fatal tuberculosis of infants, is the use of milk from infected cows. Now, these cows are themselves diseased through media very similar to those which disarm the human subject, rebreathed foul air and dirty places; in fact, want of cleanliness, and, above all, want of fresh air.

Well-ventilated cow sheds, and immediate separation of sick animals, prevent the spread of tuberculosis among cows; thus children are saved from the danger of tuberculous milk. The breath of the consumptive in well-ventilated rooms may be considered harmless. Animals have been infected by breathing the dust of sputum disseminated in the air, and no doubt the same mode of infection is very common among mankind, but only in close association with the sick or in stuffy apartments. The State board of health of Maine has issued valuable instructions to prevent the practice of expectoration except in spittoons, which may be wooden or pasteboard, and should either be burned daily or cleansed with boiling water and potash soap.

The reduction of consumption by such means and by better regard for ventilation is not only probable, but certain. In England the death rate has considerably declined with sanitation. From 1851 to 1860 it was 2,679 per million per annum. In 1888 it was 1,541. In New Hampshire, United States, the deaths from the several diseases named were as follows: From 1884 to 1888, consumption, 4,039; diphtheria and croup, 983; typhoid, 750; scarlatina, 187; measles, 160; whooping cough, 109; smallpox, 2. Here the very large proportion of deaths due to consumption, and the importance of effecting a reduction, are strikingly shown; but a similar proportion exhibits itself in every thickly inhabited State, both in Europe and America.

Rooms occupied by consumptives should be periodically disinfected and always kept clean. The danger is there, but it can be averted. The experience of the Brompton Hospital shows that with proper hygienic precautions cases of infection from patients are very rare. Koch has shown that enormous multitudes of bacilli may be distributed on the ground and in the air from only one patient, and how infection is explained by their long survival in a moist or dry state. Cornet showed how the walls and carpets, cornices, etc., retain them still potentially virulent. Thus certain houses remain for a long while centers of infection, and newcomers are attacked out of all proportion to the cases among neighboring uninfected dwellings.

Prisons, barracks, etc., which when crowded and badly ventilated were very fatally affected with consumption have been rendered wholesome by thorough ventilation and greater cleanliness. Out of an average prison population of 4,807 in the year 1890 in England, only 9 died of phthisis, excluding cases in which sick prisoners were removed home.

The mortality of the British army in barracks from consumption in the ten years 1837 to 1846 was 11.9 per thousand. After the report of a royal commission in 1858, ventilation and air space were greatly extended, and the mortality immediately and rapidly fell; in 1888 the consumption rate was only 1.2 per thousand.

The disease prevails more on wet, cold, clayey ground and damp places generally than on high and dry sites, and all causes of chills and colds give an opportunity to the infection of the specific bacilli where they are present in sufficient numbers and strength.

Cold countries are rather less subject to the disease than temperate and warm climates, but everywhere the most important factors are the habits of the people. A moist atmosphere, with wide daily range of temperature, favors its prevalence. In Greenland, Labrador, Iceland, Spitzbergen, Nova Zembia, Finland, Siberia, and the northern parts of North America the disease has been rare; also especially on mountain ranges, high plateaus, and little-visited districts, such as the Soudan. In Algeria the nomad Arabs were free from it. The Bedouins who exchange their tents for stone-built houses suffer to some extent. Many uncivilized tribes are exempt until they adopt the clothes and way of living of civilization. Outdoor life in the free air, and clean, spacious sleeping quarters almost or quite annihilate consumption if animal sources are excluded. Soldiers on campaign, fishermen, hunters, engine drivers, gardeners, and farm laborers are least attacked; workers in gritty stone or metallic dust, in hot, close, crowded, and damp rooms or factories or mines, and dwellers in damp houses, back-to-back houses, and close courts furnish the largest number of victims. In the old town of Havre, with its airless, narrow streets, the mortality is three times as great as in other parts of the town.

It has been shown that in proportion as a population, male and female, is drawn to indoor occupations, the death rate from consumption increases.

An elaborate investigation for official purposes by Dr. Ogle showed the mortality from phthisis and lung diseases of men from 45 to 65 years of age working in pure and vitiated air in England, to be as follows:

	Phthisis.	Other lung diseases.	Total.
Pure air:			
Fishermen	55	45	100
Farmers	52	50	102
Gardeners	61	56	117
Agricultural laborers	62	79	141
Confined air:			
Grocers	84	59	143
Drapers	152	65	217
Highly vitiated air:			
Tailors	144	94	238
Printers	233	84	317

From these figures the effect of the breathing of foul air on respiratory diseases is conspicuous. But the differences represented would have been much greater if the class described as living in pure air had not been subject, during that part of their lives which was spent within doors, to the bad air of close apartments or cabins, and to the occasional infection of places of assembly and resort.

That demonstrable bacilli are given out by the breath of persons suffering from consumption and other diseases, has been proved by Ransome and others. The possibility was doubted by Cornet and other authorities on the grounds that nonvolatile substances can not be exhaled, that many good observers have failed to find them, and that where observed errors may have crept into the experiments. But Cornet himself has shown that the bacilli are exhaled in small numbers by patients, and that they and their spores are given off in great numbers from handkerchiefs, bed linen, furniture, floors, etc., of rooms in which consumptive persons live.

Klein has shown that guinea pigs exposed to a spray of tubercular matter in the air, or else kept in the shaft of a ventilator in a consumption hospital, acquire the disease. It has been proved by Straus that nurses of consumptive patients have tubercle bacilli deposited on their breathing organs. These last experiments are not proofs of the exhalation of the fatal microbes. But we have the most convincing proof in everyday facts of the possibility of the exhalation of the bacilli or germs of several infectious maladies. The breath is one of the most common vehicles of transference of infection from person to person. Moreover, Ransome finds much indiffusible organic matter, such as epithelial scales, in the condensed aqueous vapor of the breath. The breath of consumptives, however, contains very few bacilli, and the particles of sputum which fall from the mouth in expectoration or in speaking are more dangerous.

Tuberculosis has been produced in animals by causing them to inhale air vitiated by subjects of phthisis. Glass slides, wetted with glycerin, show the presence of tubercle bacilli in the air of consumption hospitals. Tuberculous particles inhaled are found to be more capable of infecting than particles swallowed. The air does not often, at any rate, convey infection from the mere breath of a patient in an ordinary clean room, and the temperature must be rather high to maintain the vitality of the germ. In hot climates, under similar conditions, the danger is greater, but generally the better ventilation reduces it.

Consumption and leprosy are caused by similar microbes, and have much in common in their behavior. In phthisis the contaminated air conveys the bacillus to the air passages, and in scrofulous glands to the nearest sore; in leprosy the exposed parts, hands, face, and feet, which have received some scratch or wound, are first attacked. As leprosy has been got rid of not only by improved conditions of living, but by segregation of the victims, so consumption and tuberculosis will be exterminated wherever the utmost care is taken in providing for fresh

air, good and well-cooked food, clean dwellings and clean byres, and in segregating or specially controlling and caring for affected individuals. Close courts, back-to-back houses, damp cottages, tuberculous meat and milk, overcrowding, and dusty occupations in heated air deserve either total condemnation or most rigid precautions. Rooms should be constructed so as to be easily and frequently cleaned and constantly aired. The habit of wetting envelopes, ledger pages, etc., from the mouth should be prohibited. Notification of cases should be required as in other infectious diseases. Light, air, space, exercise, and cleanliness should be made easy of attainment and common to every human being.

TYPHUS.

Another disease intimately associated with bad air and with crowded dwellings is typhus. It does not arise at all among persons living in the open air and in well-ventilated rooms, but spreads with fatal effect in the crowded, dirty apartments of the poor, in filthy jails, ships, and lodging houses. The disease was formerly very destructive in England, infesting the prisons, and was sometimes communicated to judges and lawyers into whose presence prisoners were brought: but better conditions of living, greater cleanliness, and more regard for ventilation have resulted in its almost complete extermination. So sensitive is the microbe to fresh air and disturbance of foul surfaces that the crowding and dirt which remain, bad as they are, are scarcely sufficient to maintain its virulence. Typhus is not conveyed far by the air, and as a rule only infects those who are very near to the victim. All the staff of the Fever Hospital, in London, were attacked at some time through this infection, but during eight years no case occurred among the staff of the Smallpox Hospital, which was in close proximity. Even the attendants in typhus wards run little risk when these are spacious, well ventilated, and not overcrowded. Poisonous microbic emanations from the lungs and skin are thus in an almost incredible space of time rendered harmless by the action of fresh air.

The winter has generally been the season of greatest prevalence of typhus, owing probably to the greater distress and crowding in the cold months. The infection remains for some time on clothing, walls, etc., so that the air does not apparently disinfect or destroy where the organism has sufficient moisture and nourishment.

THE PLAGUE.

The plague, a very severe pestilence which has been common in the East and in North Africa, and has visited Europe with the most appalling mortality, arises in districts where filth abounds to the most extent, where dwellings are overcrowded, and where famine and undernourishment are frequent. It is both miasmatic and contagious. In 1603 it hardly ever entered a house but it seized all living there. Prolonged breathing of the sick-room air was the most effectual means of infection.

A moderately high temperature is most favorable to the breeding of this pest; above 86° F. it declines. Moist, alluvial soils; the banks of great rivers, such as the Nile and Euphrates; a warm, humid air; great accumulations of putrefying animal and vegetable matter in the vicinity of dwellings: dwellings surrounded by heaps of manure and almost hermetically sealed—these are conditions favorable to the growth of plague. Once started, it spreads by infection much after the manner of typhus. Care for the purity of air in and around dwellings abolishes plague altogether, as has been proved locally in the Himalayas and generally in the retrogression of the disease from Europe.

CHOLERA.

Cholera is to a great extent a disease of air poisoning. It arises from the soil in certain districts of India, where it is endemic, and from which it occasionally has the opportunity, through favoring climatic influences and the movements of travelers, of invading temperate regions, in which it may cause great mortality in a few seasons, but can hardly establish itself permanently in the soil or water. It does not, as was long supposed, travel from place to place through the air, and has no epidemic existence beyond its breeding places apart from human agency. The cholera microbe, the comma in all probability, thrives in a damp, organically polluted soil, such as that of the delta of the Ganges and the flat lands around Madras, Bombay, and Shanghai; of the valleys of the Brahmaputra, the Nerbudda, the Tapti, the Indus, and the Euphrates, and in a temperature of from 25° to 40° C. In the delta of the Ganges the temperature of soil and air appears to be so favorable that it never dies down; at Shanghai it regularly infects the air and water after the heat of July and August. It is aerobic. A freezing temperature prevents its growth, but does not destroy it. Kept moist, it may live for months after growth has ceased; dried for a few hours, it dies. In temperate climates it is spread by the entrance into water and air of the organisms derived from growth in the dejections of cholera patients, some cases being only recognized as diarrhea, but still being capable of spreading the poison. The destruction of the dejecta is, therefore, the safeguard in all cases. The power of extension of cholera through the air alone in the neighborhood of cholera patients where due hygienic precautions are observed is very small, but every article used must be washed or sterilized. The general atmosphere does not convey it either from person to person or from soil to soil, unless, possibly, in rare cases and for a short distance. In fact, free air, unless very humid, soon kills it. The atmosphere of the Gangetic delta, the chief endemic area of cholera, is remarkably damp. There are probably a number of places in India where the soil is to some extent infected, but where mischief arises only in certain seasons.

The conditions of soil and air favorable to the growth and exhalation of the cholera germ may be concisely summed up as follows:

Permeability of soil to air, moisture of soil not excessive, average soil heat at 6 feet deep about 79°, a moderate amount of contained organic matter, and little putrefaction or ordinary decomposition; mean annual temperature of air about 72° F. The minimum water level, otherwise the maximum of soil ventilation, and the maximum of cholera coincide. Dry or saturated soil are unsuitable for the continuous growth of the bacillus.

DIARRHEA.

In an inquiry conducted about thirty-five years ago[1] regarding the prevalence of diarrhea, a disease which in England is fatal to very large numbers of children, it was found that there are districts in which endemic diarrhea is unknown, and others in which it prevails extensively every year. The excess of mortality coincided in all cases with one of two local conditions, the tainting of the atmosphere with the products of organic decomposition, especially human excrement, or the habitual drinking of impure water. Since the time of the report a large amount of evidence has accumulated which goes to prove that summer or infantile diarrhea is caused by the infection of air and food by emanations from a damp organically contaminated soil raised above a certain temperature. Houses built on or near a subsoil containing decomposing organic matter, or where sewers leak, are particularly subject to diarrhea. The nature of the soil is important. Sand, loose fine gravel, deep mold, and permeable soils generally, where organic matter is abundant, are productive of the disease: houses built upon rock, without fissures, are generally altogether exempt. "Made ground," containing organic rubbish, on which so many houses in the outskirts of large towns are built, emits products of decomposition into the interior of houses and is a fruitful source of suffering. The practice of building on rubbish heaps should be made a criminal offense. The absence of free ventilation within and around houses greatly increases the mortality from this cause. Deep drainage has been followed by a marked fall in the prevalence of the disease. Paving, impervious flooring in houses, cleanliness in the storage of food, with ventilation, are important measures for its reduction. Purity of air, indeed, in this as in so many other cases, is the remedy to be sought.

Diarrhea in the epidemic form arises under conditions very similar to those of cholera. It may be in fact a very near relation of that microorganism, but is milder in its effects and has the quality of developing at lower temperatures. When polluted, damp soil at 3 or 4 feet deep reaches about 56° to 60° C., as it generally does in England in June or July, the cases of diarrhea mount up rapidly, for the diarrheal microbe is then multiplying in the subsoil and emerging through the upper stratum, and may indeed be developed in decaying organic matter on the surface. Settling upon articles of food and drink, such as vegetables, water, and milk, it multiplies and develops the poison

[1] Second Report to the Privy Council, London, 1859.

which belongs to fungoid growth. When ingested with food, and even when breathed with the air, it causes the disease. The air of that part of a town which was subject to diarrhea has been proved to contain germs which cause the disease, and to contain 2,000 to 7,000 bacteria and micrococci in the cubic meter. The deaths in this part of the town, containing one-third of the population, were 216 out of a total of 256. The remedies for diarrhea are principally draining the ground to a considerable depth, paving, ventilation of dwellings and of places where milk and food are kept with air from some height above ground, cleanliness generally, and a good water supply. Cows, farmyards, and dairies need similar attention. Diarrhea is much less common among the Irish population of large towns, owing to their infants being almost invariably suckled by their mothers and not from the bottle.

The general air soon nullifies the danger from strata near the infected ground, and the germ seems to be incapable of enduring conveyance in a potent state through any considerable distance in the free atmosphere.

TYPHOID FEVER.

Typhoid fever, like cholera and diarrhea, depends to a great extent on the growth and cultivation in neglected human refuse by human agency (unwilling but effectual) of germs which thrive in damp, polluted soil or in foul water. Warmth and exclusion from free air favor the development of the bacillus, supposed to be the cause of typhoid. It can grow, however, in the presence of free oxygen, and then develops the saprophytic habit and great resistant power. In direct sunlight it is killed in six to seven hours, and in diffuse daylight growth is very slow. The mode of entrance of typhoid is both through air and water contaminated with the products of the intestinal discharges of persons sick with the disease.

During twenty years preceding 1883, the average annual number of persons who died of typhoid in England was about 13,000, the number of those who suffered from it about 130,000. In many continental cities, the proportion is much higher. Although bad water accounts for a large number of cases, bad air, the emanations from drains through defective traps and waste pipes, also infects in very many instances. Recent experiments of great interest have shown that sewer air is capable of so poisoning the system as to lay it open to the attacks of the typhoid bacillus, which is doubtless frequently present either in the foul air or in the intestines. In this way many outbreaks are caused by the combined influence of drain air and specific microbes. The condition of farmyards near dairies whence milk is supplied to cities is too often so filthy that both air and water are poisoned. Milk has a remarkable power of absorbing gases and vapors, and is also a cultivating medium of various fungi and bacteria.

Typhoid germs, like so many others, are soon rendered innocuous by

mixture with fresh air, and there is some evidence to show that oxidation by the air in running water has a good effect where the noxious matter is largely diluted and the stream pure. In London, New York, Paris, Berlin, and perhaps the majority of places in the northern temperate zone, typhoid fever is most prevalent in the late summer or autumn, when the ground at a little depth, and water in shallow wells, are at their highest temperature. In India it occurs mostly in the hot, dry months before and after the rains, and may in part be attributed to the wind blowing up the dust of filth deposited in the fields, but chiefly to the same conditions as prevail in England and to the introduction of the virus, often from slight and unsuspected cases.

The great majority of houses in civilized places resemble inverted, slightly ventilated bell jars, connected with a system of pipes on which deadly organisms may grow, and from which they may be conveyed by the poisonous gases to the bodies of the inmates. It should be a primary object to make the entrance of these gases difficult and of the outer air easy. The bacillus concerned in typhoid fever is probably widely diffused, but, whether often present or not in an innocuous form in the human intestines, does not attack life where air and diet are pure. With the aid of impure air from drains, middens, and foul sinks it acquires deadly power. Cleanly disposal of refuse and abundance of fresh air are the great securities against this disease.

MALARIA.

Malaria is the most general, constant, and destructive of endemic diseases in tropical climates and over a very large proportion of the inhabited globe. Millions die of it every year in India, and in Africa and South America it is terribly prevalent and fatal. Vast numbers of people are crippled and diseased for life in consequence of the fever, and in many districts the whole population looks debilitated and anæmic. It depends on the emission of living organisms, probably amœbiform, from warm, damp soil, rich mold, sand, or other suitable ground containing a little organic matter. It haunts open and narrow valleys, dried water courses, the country at the foot of many mountain ranges, sandy coasts in certain climates, mangrove swamps, deltas, marshes, and even in certain districts dry, sandy plains at a considerable elevation. The organism appears to exist either in an active or latent form in nearly all hot countries where the soil contains sufficient organic matter, and that need not be much. Where soil is efficiently drained, naturally or artificially, malaria is rare or absent; and where irrigation works increase the dampness of the soil, there also malaria increases or develops itself. Cultivation, with the exception of rice growing, in general diminishes or abolishes malaria within the area cultivated. Lowering of the water level and aeration of the soil reduce malaria notably. Drainage in East Anglia has almost extinguished ague, which is a similar or the same disease. Some sandy, semidesert districts, such

as Western Rajpootana, are subject to malaria, although the water is several hundred feet below the surface. But here the sand is found to be damp a short distance below the surface, and probably the same condition prevails elsewhere in sandy tracts where malaria is present. The rainfall is scanty, but the great range of temperature probably causes a good deal of dew-condensation on the sand.

Sometimes, though rarely, rocky surfaces emit malaria, but probably the habitat of the organisms in these cases is in clefts or disintegrated rocky detritus. The efficiency of attack on the human body depends in great measure on the concentration of the organisms within a few feet of the surface of the earth in the evening hours, the difference between day and night temperature, the high temperature of the soil, and the suddenness of the fall of temperature. Although the strongest men in the best of health may be stricken, yet, in most malarious countries, the avoidance of fatigue, of indigestion, and of any chilling of the surface of the body, is an important safeguard. The conditions in which malarious germs are emitted from the soil and concentrated in the nethermost strata of the air are further considered in relation to the emanation of vapor from the earth and the deposition of dew.

YELLOW FEVER.

Yellow fever results, in all probability, from a fungoid or microbic growth, but the particular microbe concerned has not been certainly identified. It prevails habitually in the West Indies and on the coasts of the Gulf of Mexico, and these have been regarded as the original breeding grounds. But it has also long been endemic on the west coast of Africa, especially at Sierra Leone. It is easily capable of transportation, especially in the case of particular outbreaks and in particular seasons, and it has in several years, like cholera, attained almost a world-wide prevalence. When transplanted to favorable places (and these are mostly seaports with very poor sanitary conditions) it takes root and breaks out in succeeding years as if it were multiplying on the polluted soil. As a matter of fact, it thrives on damp organically contaminated soil, on the walls of houses, and on the wood of ships, in foul holds. It haunts the vicinity of drains, banks of rivers occasionally dry, harbors, and crowded rooms or houses. The manner of its growth a good deal resembles that of cholera, but its areas of prevalence are smaller, and it is more largely communicated through the air, each case of yellow fever becoming a focus of prevalence in tropical and foul conditions. It requires a high temperature for its propagation, and is arrested, but not destroyed, by frost. Strangers are much more liable to attack than residents, but residents are not always immune. The living cause of the disease clings with great tenacity to ships, walls, etc., for a long time, and is conveyed, in very many instances, by the air to persons who approach the infected object. The organic poison seems to multiply outside the body, upon foul surfaces,

and thence to infect. It is not transported by the wind—at any rate to a distance—but depends on human movements, on overcrowding, neglected refuse, and absence of proper ventilation. It seems probable, from its persistence on the coast, on the banks of tidal rivers, and on ocean-going ships, that it finds a favorite pabulum in slightly saline deposits.

DIPHTHERIA.

Diphtheria, now one of the most fatal maladies of children, both in Europe and America, is equally preventable by purity of air; but since it is commonly caught by infection, and susceptible persons are attacked through slight doses, absolute prevention is difficult. Its propagation depends to a great extent on schools and close aggregations of children, some of whom may be affected by the disease in a mild form, such as slight sore throat. Some cases arise from a disease of the cow, which is not easily identified, but the great majority of cases of the disease are certainly due to the emission into confined air of the microbes from persons already suffering with sore throat or diphtheria, and therefore the great majority of cases would not occur if schools and dwelling houses were well cleansed and ventilated, and if children with suspected throats were as far as possible isolated. The gradual growth of diphtheria in villages and towns and its frequent recurrence indicate an infection of the air in houses either from a contaminated surface soil, from floor or walls, or from the breath of persons who have had the disease and in whose throats the microbe lingers after their recovery. Diphtheria does not occur at all in clean, dry places, unless introduced by some person or imported article carrying the infective organism. The germ is certainly not present in a potent condition in the outer air. Newly inhabited countries and places have always remained free from diphtheria until the germ has been introduced by human agency.

Diphtheria and scarlet fever are among the most widely and constantly prevalent, and most fatal, of all diseases in temperate climates. They are both communicable through the air in proximity to a patient, and this is a very common mode of conveyance. But they have never been known to pass across any considerable space through the outside air. The evidence leads very strongly to the conclusion that they are rarely if ever caught by exposure to infected air which has been very largely diluted in the free atmosphere. Predisposition to diphtheria, and probably to a less extent to scarlet fever, is favored by drain air, sewer air, and the emanations from heaps of decaying animal or vegetable matter, dust heaps, and by the various causes of sore throat. And it is probable that the microbe of diphtheria, which has been identified, frequently infects the surfaces whence the foul emanations proceed. It is certainly present in very many places, especially in houses and localities where the disease has formerly prevailed. Measles are often followed by diphtheria, though no source of infection can be

discovered. Many persons after recovering from diphtheria are still capable of giving infection by the breath, for the bacillus may remain for months in the mouth and throat. Cases of sore throat which may be slight often communicate to other persons, in consequence of aggregation in foul air, severe sore throats and diphtheria. It seems that the disease may be a slight one until by the effects of rebreathed air it develops fatal virulence. For this reason, and owing also to the opportunities of ordinary infection in confined air, diphtheria is a disease which largely depends on schools for increase and propagation. It haunts the surfaces of objects which have been exposed to it, and thorough disinfection is required to remove it. The autumn and winter season, damp dwellings, damp soil, dirty farmyards, privies, etc., favor its development; but its continual increase has been due to increased school attendance, meetings, etc., and to the increase in the number of infected places, and in the means of quick traveling. Ventilation, much more thorough than any now generally practiced, combined with the better disposal of refuse, must be the principal hygienic measure to reduce its prevalence. Investigation of the conditions under which it survives in places and houses, and of the effect of ventilation and proper space in schools in preventing its propagation, is much needed.

PNEUMONIA.

Two or more different diseases are known under the name of pneumonia. The temperature of the air is an important factor in its production, but all countries are subject to it. The maximum number of deaths from this infection occur in December, the minimum in August. Cold is a strong predisposing, but not the ultimate cause. Overcrowding, the want of ventilation, emanations from sewer and filth, play an important part in epidemic outbreaks. Certain bacilli or micrococci are concerned in the production of epidemic pneumonia, and possibly the commonest form of pneumonia is due to the opportunity given by cold or by foul gases for the attack on the body of an organism frequently present in the breathing organs. There is little evidence as to the exemption of persons living entirely in the open air and thoroughly well-ventilated dwellings, and not exposed to infection from others, but the probability appears to be that many persons have in themselves a cause of a certain sort of pneumonia which may attack them through a chill, but that the breathing of purer air and the prevention of infection through the breath would greatly reduce the number of victims. The typhoidal character of some forms of pneumonia and their mode of origin and spread suggest a connection with soil poisoning and contamination of superjacent air. On these points investigation is needed.

Pneumonia is very apt to occur after colds, measles, typhoid, malaria, and especially influenza. If it be due to a particular micrococcus, the organism must be very widely disseminated. But probably several different organisms are capable of thus affecting the weakened constitution,

and the disease named pneumonia is the result of different causes which need more distinct classification than they have yet received.

Dusty trades and smoky fogs favor the incidence of pneumonia.

BRONCHITIS.

Bronchitis, one of the most prevalent and fatal of all diseases in cold and temperate climates, is often directly due to the effect of cold and of a sudden fall of temperature. Although much less common and fatal among people living in healthy conditions, it nevertheless often attacks strong constitutions, even in the purest atmosphere. Fatigue predisposes. A great deal of preventable bronchitis results from imprudence in clothing and in diet—for instance, alcoholic excess—but much also from breathing dusty and smoky air. A smoky fog of some days' duration in cold weather in London causes a heavy mortality, while a fog in the country has little effect. Much bronchitis results from weakness and chill following illness and fatigue. Changes in the blood and accumulation of waste products are apt to follow excessive exertion. The importance of warm clothing and of breathing air free from smoke and dust, especially the dust given off in the manufacture of hardware, pottery, lead mining, etc., is great in the prevention of this disease. Close rooms where gas is burned contribute largely to bronchial attacks, and in general purity of air is one of the first conditions tending to immunity. But cold and damp seem to be quite sufficient to produce bronchitis in some constitutions, and in young children and old people, apart from anything like infection from outside. Indeed, it seems likely that an excess of ozone, or else a cold, bracing air, often determines an attack, and these qualities are beyond doubt sufficient greatly to exacerbate symptoms resulting from a slight cold or chest weakness. A soothing, soft, warm, damp air, on the contrary, quickly ameliorates the condition of a sufferer from bronchitis, cold, or cough; the extraordinary power of a whiff of cool, fresh air to increase the malady, and the ill effect of even a glass of cold water, seem to show that the bronchial tubes, capillaries, and air passages are in a highly sensitive state and that temperature is a matter of extreme importance. Experimental investigation of the temperature and condition of air most tending to rapid recovery from bronchitis might disclose facts of importance in the connection of inflammatory states with the atmosphere. It seems not unlikely that an absence of ozone, deficiency of oxygen, and excess of vapor of water, and of nitrogen or carbon dioxide, might prove favorable.

RHEUMATISM AND RHEUMATIC FEVER.

Few diseases are more common or cause more suffering than rheumatism, acute or chronic. A great deal has still to be discovered respecting its external causes. It prevails much more in some districts than in others, and certainly in many cases the mischief is brought into the human system through the air. Damp and cold in soil and air,

and chill in the body, especially when feeble or fatigued, are main factors. As in so many other maladies, the specific cause in rheumatic fever may be the entrance of a micrococcus or other germ by means of a chill, either in hot or cold weather. An inquiry into the distribution of rheumatism, with regard especially to soil, climate, air, and dwellings, and eliminating as far as possible predisposing human habits, would furnish results of much value. There is some indication, as in the case of malaria, that air near the ground in low places has much to do with the incidence of the disease. Damp dwellings and clothes conduce to an attack, and to the chronic form. It seems very probable that it would be found that persons removed from ground air, as in the attics of high buildings, are exempt from attack, except through food and drink.

MEASLES AND WHOOPING COUGH.

Measles and whooping cough are spread chiefly through the air to persons in the immediate neighborhood of the sick, and of articles, especially clothing, which have been exposed to the infective matter. Segregation, ventilation, and avoidance and disinfection of materials which may disseminate the disease are effective in prevention, where they can be carried out. In the early stage of measles, as of influenza, even while the symptoms are slight, the germs of the disease may infect through the air, and therefore measures of precaution are difficult. The best preventives against widespread and severe attacks are habitual regard for sufficient air space and warmth and immediate isolation.

DENGUE.

Dengue is a disease somewhat resembling influenza in its symptoms, but prevalent only as an occasional epidemic in tropical countries. It is apparently spread by infection in the air from case to case, but not through the general atmosphere. The reason of its failure to extend beyond hot climates is quite obscure, but it would seem as if it required, like yellow fever, a high temperature outside the body in order to grow and disseminate germs fitted for infection.

SMALLPOX.

Smallpox has been ascertained by several careful investigations to be capable of passing through long distances, at least half a mile or a mile, of fresh air without losing its power of infecting susceptible persons. The experience of hospitals in London and Paris is well known. Recent observations on the spread of smallpox from a hospital near Leicester, containing 49 patients, showed that a number of cases which occurred in a suburb about 300 yards distant were in all probability due to transport by the wind. The epithelial scales and dust of smallpox cases are rather peculiarly protected from atmospheric influences, and the conditions of the survival of exposed germs need inquiry.

INFLUENZA.

No disease of the epidemic character has seemed to depend more on the constitution and infection of the general atmosphere than influenza. Its rapid spread, its apparently capricious outbreaks at places wide apart, the almost simultaneous attack, as it seemed, upon a large fraction of the population of a country, masked the true method of progress. But when its track and behavior were carefully followed, these facts became clear—that it never traveled faster than human beings; that many mild cases existed in every large town long before it was generally recognized; that it took at least six weeks to attain its maximum after the occurrence of the first cases; that its rapidity of advancement from east to west and from town to village corresponded roughly and generally with the rapidity of means of transit; that large numbers of people not exposed to personal infection escaped; that islands unvisited through the period, deep-sea fishermen, and light-house keepers escaped, except in a very few instances where they had been ashore or received communications from infected places; that susceptible persons very easily caught the pest within a few days after exposure to infection in the ordinary sense; that infection was sometimes conveyed by parcels, letters, clothing, etc., from patients or infected places; that ships which had cases on board were the means of starting it in islands at which they stopped; and that in previous epidemics the spread was often so very slow as to be quite unaccountable by any atmospheric quality. Moreover, when the bacillus of influenza was identified, it became easy to comprehend how the countless multitudes of exceedingly small organisms alive in the sputum and saliva might be disseminated in the air of buildings and of public conveyances and transmitted from place to place by commerce and the post. The general atmosphere either diffused them to harmlessness or killed them, for there was no evidence of influenza reaching an isolated community by means of wind blowing from a place where it was prevalent. But in confined or foul air they were capable of passing through many feet without losing their capacity of infection. They were experimentally shown to thrive abundantly on the gum of an envelope,[1] and since many patients wrote letters, this must have been rather a common mode of transmission, the organic motes flying upward to the breathing organs of the recipient on his breaking the fastening. There is no difficulty in explaining the quick diffusion of an epidemic having the qualities of influenza among a susceptible population. The minuteness of the bacilli, their vast numbers in the breathing organs, the short period of incubation, and the early infectiveness, and in modern times the immense daily communications between distant places, have to be taken into consideration. If examination of matter of the

[1] Dr. Klein, British Medical Journal, February, 1894.

tenuity of smoke particles, or of the minutest microbes, could be undertaken, with a view to determine the rate and extent of its diffusion by human communications, it would probably be found that very few districts in the country are out of microbic touch, as it were, with all the chief centers of population for a single day, and none for so long as a week; and certainly the air inclosed in a packet from an infected place, when suddenly liberated, would be likely to bear with it active seeds of mischief. But the great majority of cases of influenza were due to proximity to a person already attacked. Most people in the course of a day come into association with ten or twenty others in more or less confined spaces of air. If only one in five catches the influenza, and so on in the same proportion, a fourth part of a large city may be struck down in a very few weeks. In general, one-half or three-fourths escape, being insusceptible, or less susceptible than others, or less exposed to the virus. Where large numbers of persons work together in one ill-ventilated building, the proportion of attacks is much higher, other things being equal, than where people work at their own homes. But the frequent opportunities of infection at meetings, social gatherings, public houses, in public conveyances, churches, and chapels tend to reduce the inequalities which would otherwise be conspicuous. The distance of air through which influenza can strike has not been well ascertained, circumstances being very different, and some forms, such as the catarrhal, being apparently more easily diffused than others. The maximum distance in the recent epidemics, for susceptible persons, could hardly have been less than 100 feet in close air, and 4 feet in the open. Isolation, where practiced, was successful in so far as it was strict. But the intercourse of ordinary life makes isolation impossible for the general population when once an epidemic of influenza has been allowed to attack a number of centers. Strong measures against importation from other countries and immediate isolation and supervision of the few cases which would occur might succeed in staving off a national infliction, for the precautionary measures would not need enforcement beyond the brief period of its prevalence in neighboring countries. Not only the high mortality, but the enfeeblement of millions of breadwinners for months, years, and even for life has to be considered in connection with the expense of preventive measures. This expense would only be a small fraction of the losses incurred by permitting the pestilence to rage unchecked.

As regards weather and climate, cold is distinctly conducive to the spread of influenza, probably for several reasons: (1) The stillness which often prevails in frost; (2) the closing of windows, etc., and the closer association; (3) the greater prevalence of colds, bronchitis, etc., laying open the breathing organs to attack. The first epidemic in London, at the end of December, 1889, was ushered in by fog and frost, and apparently rapidly reduced in severity by the mild and strong winds of the latter half of January, 1890. The epidemics in succeeding years were

much more severe, although they came upon a population to some extent protected. At the same time there can be no doubt that an epidemic may occur in any climate and in any weather. The tropics are not exempt. An instructive instance of the subtle diffusion of influenza occurred in a village of Central Africa, which was attacked immediately after the arrival of two natives from an infected place far distant. But outdoor life and less constant communications prevent the quick diffusion and wide prevalence which belong to civilized nations in temperate climates.

The manifest, at present the only practicable and yet difficult, measures for preventing these great and very destructive epidemics are: Precautions against the introduction of the pest by travelers and by articles sent from infected districts; immediate compulsory notification, without fee, of all cases occurring in a district to the medical officer of the district and through him to the central board; isolation so far as can be arranged of all the early cases in a district at the homes of the patients; prohibition of attendance of infected persons at any assemblage; and publication of the importance of ventilation, and of living, warmly clothed, as much as possible in the open air, unless actually stricken. During the period of illness, and for some time after recovery, the greatest care is required to avoid chill, which often induces pneumonia or other evils. The fresh outer air can only be safely breathed when the symptoms have subsided and when the strength has partially returned. It is remarkable that cold air alone, however pure, seems capable of causing a relapse when the system has been greatly enfeebled and the breathing organs left in a highly sensitive condition.

COLDS.

Colds and sore throat have never received the attention they deserve from an etiological point of view, owing probably to the slight character of the majority of cases. Yet they are important, first for their wide diffusion, endemicity, and frequency, and secondly for their effect in giving opportunity for the attack of more serious disorders, among which may be mentioned diphtheria, measles, pneumonia, bronchitis, and consumption. Close observation for many years has led the present writer to the conclusion that though primarily a chill, that is exposure, insufficiently clad, to a draft or cold air, is very frequently sufficient to give a slight cold or sore throat, or the feeling of one, yet severe colds are caught in general either (1) in marshy or low and damp situations, or in conditions somewhat similar to those which produce malaria; or (2) by infection from persons after the manner of other infectious diseases. It would appear as if the microorganism, or one species of microorganisms, which sets up a sore throat and severe cold, inhabits the upper layer of earth, especially in damp or marshy places, where decaying vegetable matter abounds, and passes into the air, especially in summer and autumn evenings when the earth and water

are still warm and the air is rapidly cooling. When the microbes are dense in the humid and misty low stratum of air, and when the human body is being quickly chilled, they are able to attack successfully. The microbe is probably a very common and widely diffused one, and may be present in comparatively small proportion and in less vigor in the lower air generally over the land. At sea it would be absent, and indeed there is good evidence that it does not bear long transport in a virulent state in the free air. Colds are scarcely ever caught on the open sea, even if the clothes be wet with salt water, and breezes straight from the Atlantic do not seem capable of inducing sore throat or cold. But, of course, to make an experiment crucial, previous life in the open air, disinfection of clothes and if possible of the breathing organs, would be necessary. It is not improbable that the microbe of colds, like that of pneumonia, may be frequently present in the mouth. The experience of St. Kilda,[1] which used to be absolutely free from colds until the annual boat arrived from the mainland, points to the ordinary presence of the infective particles on clothes or in the breath. The islanders were nearly all struck down with severe colds within a day or two after welcoming their visitors. Probably a similar dose of infection would be quite insufficient to prostrate persons on the mainland who were accustomed to the petty assaults of the microbe, and protected by scarcely noticed symptoms of catarrh.

An exactly similar thing occurs in the case of influenza. Hundreds of instances were observed in which the proximity of persons who had had influenza or had been near cases of influenza gave it to others, and often persons lately arrived in a place which had passed through the epidemic were struck down while the great majority of the resident population remained protected, at least for some months.

Colds protect against their own recurrence in most people for some months. Severe colds go through a house after the manner of an infectious disease, and can be similarly guarded against by isolation. The air certainly conveys a cold for several feet through confined air, and in a closed railway carriage susceptible persons who have been free from colds for some time are easily infected. An attack is often attributed to a chill felt at the beginning of the infliction, but in reality the cold has usually been caught some hours or a day or two before, and the feeling of chill is simply the beginning of the disorder, as in other infectious maladies. On the other hand, there may be a real chill, which gives opportunity to the microbe to make its attack and produce a feverish cold in a day or two. Foul air and crowded rooms are eminently conducive, especially if combined with drafts, to disseminate colds.

Persons arriving in town from the pure air of the country or from a sea voyage are very apt to catch cold. They have been living apart

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[1] And other islands. See Darwin's "Naturalist's Voyage." Report of the Local Government Board; Epidemic Influenza, London.

from the constant presence, and, as it were, the vaccinating influence, of the germs in bad air. From similar reasons horses, when brought from the country to London stables, very frequently fall out of sorts to the extent, it is said, of 95 per cent, and sheep, when placed among imported apparently healthy sheep, often fall sick. Texas cattle fever is caught from apparently healthy cattle. The first intercouse between Europeans and natives is attended with the introduction of fever, dysentery, or other diseases.[1]

SEASONAL AND GEOGRAPHICAL DISTRIBUTION OF INFECTIOUS DISEASES.

Many of the spreading diseases are more or less wont to rise toward a maximum and to fall toward a minimum at certain times of the year, and these seasons are generally nearly the same in similar climates in the same hemisphere, but there are many particular instances of variation.

Scarlet fever is a disease chiefly prevalent in the northwest of Europe, moderately prevalent in Russia, North America, and parts of South America, the coast of Asia Minor, Italy. Turkey, and Greece, and quite uncommon in Asia and Africa. It is not frequent in Australia. Its maximum in London occurs in October, its minimum in April. In New York its maximum is in April, its minimum in September. In England, generally autumn is the time of maximum prevalence. In the whole of Europe and North America 29.5 per cent out of 435 epidemics are recorded as having occurred in the autumn, and 21.8 per cent in the spring, the period of minimum; the remaining 48.7 per cent took place in summer and winter. A dry air with little rain seems to increase the prevalence of scarlet fever.

Measles, in London, has two maxima, one in December and a lesser one in June, and two minima, one in September and one in February. Measles occurs nearly all over the world since the great extension of commerce, and seems to be little affected by climate. Cold weather, however, favors it, as might be expected, since it infects through the air of close rooms.

Influenza, typhus, relapsing fever, smallpox, whooping cough, croup, pneumonia, not only prevail most in cold weather, but in cold countries, where there is least outdoor life and least fresh air in rooms and most crowding. Diphtheria increases with the cold weather of autumn, but tends to decline in February, and is at a minimum during the hot months. Cerebro-spinal fever, which is a good deal connected with crowding in large numbers in institutions, etc., not only attacks most in cold weather, but in cold or temperate countries. The relation between the temperature and the disease seems to be indirect, and the causation and dissemination of the malady are obscure.

[1] Williams, quoted by Darwin, "Naturalist's Voyage."

Consumption or tuberculosis is most prevalent where the air is moist and the daily range of temperature large.

Typhoid or enteric fever is most common in the autumn and much less prevalent in May and June. There is a sharp decline in its prevalence in London in December. In New York, and in large towns in Europe, the maximum is decidedly apparent in late summer or autumn. The variation of prevalence according to season seems to show a distinct connection between the development of the bacillus and the temperature of soil and water, and considering the long incubation and duration of cases the maximum of infection must take place at the very time when the temperature of the soil at 1 or 2 feet deep is about at its highest.

Cholera, diarrhea, yellow fever, and malaria, the poison of all of which arises from the soil and surroundings into the air, are much more prevalent in the hot season and in hot countries.

CONDITIONS OF INFECTION THROUGH THE AIR.

In order to obtain a true conception of the manner in which the virulent matter of infectious diseases may be conveyed through short distances of air, either directly from a patient or indirectly from objects which have become infected, we have to consider those cases in which susceptibility is greatest, for these afford the truest criterion of the capability of the survival of pathogenic microbes, and the best measure of the precautions which should be adopted to exclude not only persons of average susceptibility, but the most susceptible, from the area of danger. In cases of pyæmia, of puerperal fever, and of smallpox, not only ordinary measures of disinfection, but abstinence from attendance on susceptible persons for some time, is recognized as needful. In cases of influenza, diphtheria, and scarlet fever less care is exercised, except in regard to certain susceptible states. In all of these diseases, however, transmission is far too frequent, and as a matter of fact the required precautions are not duly observed. The strict regulations of dress and washing enjoined upon nurses are almost equally applicable to medical attendants, and the use of clothes of a washable material and smooth surface by all persons in the presence of infectious cases would give greater security to all patients visited, and, indeed, to the general population. A square inch of cloth can easily hold upon its surface 10,000,000,000 microbes of influenza, so that it is quite conceivable that a man may carry on his clothes many more of these organisms than there are inhabitants on the globe, and that many scores of thousands of these pass into the air of every room which he visits.

Similarly, in the cases of other diseases which pass largely by the breath and by deposited particles, there must always be a certain number on every person who visits the sick room, and although the majority of people fall victims only to rather large numbers or a high degree of

virulence, still, in order to avoid the setting up of fresh centers in susceptible people, disinfection and washing are indispensable.

The most remarkable instance of immunity from infection of a maternity hospital is that of the Grand Duchess Catherine, at St. Petersburg, one of the most carefully regulated in the world. Every utensil, instrument, and article of clothing is rendered aseptic and kept so. A vacated room is at once stripped and disinfected. The floors are mosaic concrete, the walls tiles and parian cement. Floors and walls are thoroughly washed. The result of this extreme care was that during three years there was only one case of puerperal fever, and that was brought in from outside.

A boiled vegetable or animal infusion in a test-tube may be kept an indefinite time without change or fermentation when ordinary air and objects are excluded, but a mere touch of the finger or of some object which has been lying in a room infects with microbic life and the fluid goes bad. The comparative infrequency of the conveyance of some of the infectious diseases from one to another by means of a third person is less due to the absence of the germs than to the average resisting power of the human body. The precautions taken to prevent the spread of foot-and-mouth disease in sheep and cattle well illustrate what is necessary for the protection of human beings. In an outbreak in England in 1892, a strict watch was kept to prevent the passage of any infected article, and no one was permitted to come in contact with cases of the disease excepting those persons who were provided with a proper dress, which could be easily disinfected. If these and similar measures had been customary for some years for the prevention of epidemics in man, the belief in an "epidemic constitution of the atmosphere" or in "aerial transmission" by wind for long distances could hardly have survived. The recent pandemic of influenza has given occasion for the revival of these hypotheses, which were successively overthrown in relation to consumption, the plague, cholera, yellow fever, smallpox, and even rabies or hydrophobia. Recent investigations have, however, proved beyond all doubt that the atmosphere does not, except possibly in the rarest instances, convey the virulent matter of epidemics from place to place, and that there is no security against infection so great as life in the open air and good ventilation. In fact, the atmosphere is the great reservoir of purifying agents and the most important of all disinfectants. In close places the air, deprived of some of its oxygen, filled with moisture and the impurities of respiration, can not exercise its beneficent function, and in crowded rooms infection becomes easy. So, also, cholera and other infectious matter retains its virulence in packages or stored clothing. Under the open sky and in pure air few species of pathogenic germs can pass many feet unscathed.

Consumption is typical of the class of endemics which can be caught either directly from a patient or indirectly through infected objects in

close air. People who live entirely in the open air and in well-ventilated, clean places do not suffer from it, except in the few cases where it may be inherited or introduced from without. It is a disease of civilization, and many countries have been unaffected until the virus has been brought by human agency.

Soil is not concerned in the prevalence of most endemic and epidemic diseases, though many may have originally sprung from the soil, and some have located themselves in certain areas from which they spread over the globe. The small part played by soil emanations in the great majority of spreading diseases is exemplified by the extension of epidemics and of endemics like consumption, diphtheria, measles, and whooping cough, in countries which are covered with snow and congealed with frost. When once introduced they pass among the population whose habits are favorable to their growth. In islands, again, when an infectious disease, such as measles or influenza, is introduced, it spreads as fast as in countries where the soil might be supposed to nourish the bacillus or micrococcus independently of the human body. On board ships and in isolated institutions where opportunities are given by association, many infectious diseases spread just as they might in inhabited places, whatever the soil. At the same time endemicity is largely a matter of soil and habitation. Infection from person to person, and to a great extent through confined air, may thus be separated off as the main condition of prevalence of infectious diseases.

Diseases capable of transmission for a short distance through the air may, for present purposes, be divided into the following classes:

(1) Those which arise from damp soil or subsoil in alluvial plains, deltas, valleys, mangrove swamps, certain sandy coast districts, and other situations. Malaria, intermittent fever, and ague are the chief diseases of this type, and are in general not transmissible from person to person. They are transmissible a few miles through the air from the locality of origin. Colds and sore throats probably arise from similar conditions, and are infectious through a short distance of air to susceptible persons. Forms of dysentery and certain diseases of the liver, etc., seem to be due to conditions largely corresponding with those of malaria.

(2) Diseases which arise in somewhat similar conditions, but seem to have required not merely vegetable matter, but a large population and neglected filth in the soil and water for their development. Cholera belongs to this class, and depends to a great extent on human filth in the soil and befouled water. Cholera is infectious from person to person through the air, but only to a slight extent, and depends for its existence beyond its habitat on access to filthy soil, water, or places where it grows, multiplies, and infects the air, as well as other matter, which gains access to the body. Typhoid grows on damp human filth and may infect persons who breathe the air arising from such filth, especially in houses and confined places. The air in the neighborhood

of a typhoid case does not appear to convey the disease, apart from excremental matter exposed to the air. Yellow fever seems to grow in conditions somewhat resembling those which are favorable to cholera—filthy, damp surfaces in great heat—and infects the air in the neighborhood of its growth, especially banks of rivers, harbors, holds and bilges of ships, and dirty, dark, crowded streets. It sometimes infects direct from a patient. These three saprophytic or semisaprophytic diseases may be supposed to be propagated a short distance from place to place through the air without the intervention of a human subject, but have never been known to be carried far independently of human transporting agency.

(3) Diseases which arise from deposits of organic matter from the lungs and skin, and also probably from other excrementitious filth. Typhus and the plague may be named in this class, but other conditions of filth are powerful in their genesis. Plague is both miasmatic and contagious, and, where concentrated, seems to be capable of passing through several hundreds of yards of air. Prolonged breathing of the sick-room air both in plague and typhus is the most effectual means of infection. Damp, alluvial soils; streets, walls, and floors with damp organic deposits sticking to them; carcasses and refuse lying unburied around houses; in these situations the plague fungus flourishes. Diphtheria arises probably from somewhat similar breeding places, from heaps of house refuse, from middens, drains, ash heaps, and polluted ground, floor, and walls, and is transmitted a short distance through the air, probably seldom more than 10 or 20 yards. It is very often, probably in the majority of cases, carried by the air from person to person through a short distance, most easily in damp, close, or confined air, like so many other infections. The diphtheria fungus, when it has been once introduced, sticks to certain places, damp houses and damp organically polluted sandy soil seem to favor it. It is improbable that it is ever conveyed far from place to place through the air to persons except by human agency and the movements of domestic animals. Pneumonia may possibly depend on somewhat similar conditions, and may be caught by one person from another through the air. Consumption, phthisis, or tuberculosis, depends to a very great extent on conditions similar to those of typhus, and is spread through the air a short distance in the dried matter of saliva and sputum.

(4) Scarlet fever, measles, whooping cough, influenza, and dengue arise from conditions outside the body which are unknown, but decaying organic matter may provisionally be assumed to have been their original breeding ground. They are now almost entirely dependent on transmission from person to person, and to a very large extent on transmission through a short distance of air. It is very seldom that these maladies are caught in the open air, so that the medium of transmission is the confined and more or less foul air of schools, houses, churches, and theaters. They are never caught in isolated positions in

the open air, in islands to which no infection is brought by human agency, and in well-ventilated institutions where every possible precaution against infection from without can be rigidly maintained. Even the Isles of Scilly, near the southwestern coast of England, were free from measles, scarlet fever, and smallpox for ten years, the only district exempt out of over seven hundred in the whole country. It was also one of the seven districts in which no death from diphtheria occurred.[1] Since communication has become frequent, owing to a great increase in trade, the immunity does not continue, and influenza broke out there only a few weeks later than on the mainland. Another island, Alderney, was affected early by influenza through the examination of goods by custom-house officers, who caught the infection soon after the arrival of the steamer.

PREVENTION OF SPREAD AND PREVALENCE OF VARIOUS MALADIES.

Prevention of the spread of these various classes of disease, the reduction of some and the extinction of others, may be effected by the following means:

1. *Malaria class.*—Drainage, cultivation, planting, proper disposal of refuse and carcasses. In places where a small area of moist ground or small marsh gives off the dangerous exhalations, the surface might be covered with a film of crude petroleum to prevent the escape of the germs. Other experiments on the treatment of the surface of the ground with antiseptic mixtures might lead to valuable results. Powdered charcoal, and lime, might be tried.

2. *Cholera class.*—Proper disposal of refuse, drainage of soil, cleanliness and airiness of streets, houses, quays, ships: prompt disinfection and cleaning of places where first cases occur; prevention of overcrowding. Where any damp surface, as in a midden, pool, or drain, is suspected of giving off dangerous emanations, crude petroleum might have the effect of imprisoning the germs by an impervious film. Experiments are needed on means for the exclusion of living organisms from the air, where they are numerous, by treatment of the surface soil; also on substances inhibitive of their growth, which might be used on a large scale.

3. *Typhus class.*—Cleanliness and good ventilation of dwellings and of their surroundings and avoidance of overcrowding in houses, schools, etc., prevent this class of disease from arising, but ordinary personal infection has to be attacked also by isolation on the occurrence of the first symptoms. The inside walls, floors, etc., should be of some impervious material, easily and frequently washed. A dense cement or hard wood may be suitable; but, whatever the material, liberal ventilation and cleansing are required to prevent deposition of organic matter and growth of fungi. In schools, etc., the walls should be of smooth cement,

[1] Public Health Reports. Sir John Simon.

glazed ware, glass, or metal, and the floors of close, hard wood or common tiles. The bacteriological examination of various wall and floor surfaces, and of the air inclosed within them, would be of great service with a view to the prevention of organic deposit and emanations.

4. *Measles class.*—Cleanliness of surroundings and ventilation are required as in the last class. Isolation on the occurrence of the first symptoms, use of glazed or washable materials for the room where a case is treated and for the outer clothing of attendants, absence of carpets and hangings, and frequent thorough sweeping, cleaning, and airing would greatly reduce the number of centers of infection. Where many people work or meet together, the air must be kept as fresh as possible. Influenza is best reduced by immediate isolation or segregation of the first cases in any place, and by avoidance of meetings in confined spaces. The distance of air, confined and open, through which various infections common among mankind and animals can pass should be determined by comparison of records and by actual experiments on animals.

The effects of the free air in healthy regions, neither very low nor very high, neither very hot nor very cold, may be summed up as supremely beneficial to human life and health. The most healthy class of people are fishermen, sailors, and gardeners, yet some of these are affected by close cabins, and others by surrounding zymotic diseases. The most healthy creatures are the birds and wild animals in fairly warm climates; a little less healthy are the sheep and oxen which are never stalled; much less healthy are the stalled cattle and horses; least healthy of all the higher orders of living beings are men in crowded places.

The conditions of greatest security against endemic and infectious diseases are also the conditions which conduce most to robustness, physical and mental vigor, and enjoyment. Outdoor life with sufficient work or exercise can not, with impunity to the race, be forsaken for purely intellectual and sedentary pursuits.

IMPORTANCE OF FRESH AIR TO HORSES AND CATTLE.

Mr. Fred. Smith, professor of the Army Veterinary School at Aldershot, has shown the great importance of fresh air to horses in stables. The air of buildings in which animals are kept has received very little attention except in the army, but the results obtained by better ventilation wherever tried are remarkable. Warmth derived from the animals only, in a cowshed or stable, is evidence of foul air; ventilation should be by good-sized opposite windows, and by roof-ridge exits; and if necessary, artificial heating should be employed. Cubic capacity per head should be 1,600 feet. The majority of preventable diseases among animals are traceable to food and feeding, but "certainly next to this comes impure air." By good ventilation and care for cleanliness glanders has been entirely got rid of, a disease from which hundreds

previously died annually; pneumonia has been greatly reduced in prevalence and intensity; ophthalmia has nearly disappeared, and the animals are much less susceptible to colds and coughs. "Cattle plague, pleuropneumonia, variola, and probably tuberculosis are undoubtedly spread by the medium of the air in infected areas." This class of disease can therefore be absolutely stamped out, and there are other diseases, such as horse influenza and pneumonia, which, with better knowledge of atmospheric influences in connection with the specific cause, may come into the same category. Infected places should be treated as if in a state of siege.

Port inspection, as regards some of the worst animal diseases, it is impossible to estimate too highly; for instance, in the years up to 1886 the number of cases in Great Britain of foot-and-mouth disease was 1,993,149; since that year almost the only cases occurring have been those which had escaped detection at ports in a very few instances, and certain other cases which had been in their proximity. All these were traced and most severely isolated, so that the country is saved from great agricultural disasters by the constant vigilance of the central and port authorities. Since many animal diseases, including tuberculosis, glanders, foot-and-mouth disease, anthrax, actinomycosis, scarlet fever (a slight eruption in the cow), and diphtheria, are transmissible to mankind (some of them, but to a very small degree so far as is known, through the air in proximity), the immunity of animals from disease concerns not only the wealth, but the health of the community. Further inquiry is needed as to the transmissibility of horse influenza and pneumonia through the air, and as to the connection, if any, of these with human maladies of a like character.

THE INFLUENCE OF CLIMATE ON MENTAL AND PHYSICAL QUALITIES AND ON NATIONAL HEALTH.

The influence of atmospheric qualities upon the bodily constitution and health, upon the mind, and upon the enjoyment of life, is eminently worthy of consideration. When we come to examine closely into the manifold causes which contribute toward human happiness, we find that, upon the whole, comparing acclimatized races, the differences in the results in regard to all except extreme varieties depend at least as much on human, artificial, and removable causes as on climate and on atmospheric conditions. The peasant of Norway may be as healthy and as happy as the peasant of Italy, the native craftsman or the ryot of India as contented though not so vigorous as the woodsman or farmer of Canada, the African negro of the equatorial zone and the uncorrupted Greenlander may physically enjoy life as much as the English or American laborer. The peculiarities and tendencies of race can hardly be separated in the account from the effects of climate. Broadly speaking, however, we may safely affirm that, apart from the special and preventable evils of a high civilization, the most vigorous, flourishing,

intellectual, healthy, and progressive people of the world are those which inhabit the temperate zones. Within the tropics the strongest and most energetic peoples, bodily and mentally, are those living in the mountains or at high altitudes. The inhabitants of low ground in hot climates are inclined to be listless, uninventive, apathetic, and improvident. They live for the day, shut their eyes on the future, and have a leaning toward fatalism. An equable high temperature with much moisture weakens body and mind. No long-established lowland tropical race is a conquering race in the widest sense of the term, or forward in the march of intelligence. But certain nations have the power of resisting, at any rate for a long time, the enervating influence of a moist, warm climate, with the malarious fevers which commonly belong to it. The Arabs and Chinese evince extraordinary power in this respect. The Arabs not only thrive in their own hot, dry country, but on the coast and in the interior of Africa, where the negroes are driven like sheep before them. The Chinese make excellent and most industrious laborers, even in the climate of Java, Sumatra, and Borneo, and where neither Malays nor Europeans persist in the hard work of cultivation. Their fare is rather scanty, and, as a rule, entirely vegetable. The Italians and Spaniards, again, can withstand hot climates better than most Europeans. The Spaniards have greatly multiplied in Cuba, the Portuguese do not desert the oppressive forest regions of Brazil. The natives of the South of France thrive in Algeria better than natives of the North of France. On the other hand, the people of northern Europe, if they do not themselves suffer much in the tropics, rapidly degenerate, and the race either becomes extinct or greatly enfeebled in a few generations. In Java, Europeans do not live beyond three generations. It was shown many years ago by a distinguished lady, and has now to some extent been long recognized by military and civil authorities in India, that a very large part of the excessive British mortality in India was owing in the first place to removable insanitary conditions, and in the second place, to faulty diet and personal habits. The realization by the governing authorities of the true and possible conditions of living in a hot climate has led to a large reduction in the rates of sickness and death. Stokvis has shown how in recent years Europeans have lived much better than formerly in the tropics. Even children to the number of one hundred or more, from the age of infancy to the age of 18 have grown up well in an institution in Calcutta, where they were carefully tended. The improper and excessive consumption of animal flesh, spirits and beer, and the disregard of simple hygienic rules, still continue to give to climate an ill name which fairly belongs to habit. Making full allowance, however, for these preventable causes of disease and degeneration, the fact remains that children can only with difficulty grow to due strength and capacity in the climate of India and the lowland tropics generally. They begin to flag after their fourth year. Common experience demonstrates

the impracticability of colonizing the equatorial zone with the races of the cooler temperate regions. Even the high stations on the hills, where the temperature may not be above that of the home country, are not sufficiently favorable to the continuance of the family and to permanent settlement. The air, though cool at night and agreeably warm by day, is somewhat too much rarefied, and the sun shines vertically. At 7,500 feet the pressure and density of the air are lessened by one-fourth, and the sun's heat increased by many degrees.

Australia is not yet proved to be equal to the Mother Country as a permanent home for the Anglo-Saxon race; indeed, there is some evidence that the British standard is not maintained, but this is largely accounted for by causes which may be considered within human control.

Hot climates are not favorable to emigrants above 44 years of age or to children under 16, and field labor can not well be undertaken.

While Europeans visiting hot, moist climates are apt to be attacked in the bowels, the inhabitants of hot climates visiting Europe and North America are especially attacked by, and often succumb, to diseases of the respiratory organs. The cold countries are unfavorable to the establishment of tropical races. A similar relation seems to hold here between cold and respiratory diseases and heat and bowel diseases, as we have seen to prevail in winter and summer in temperate climates, but the effect is accentuated when the subject is unacclimatized. That the natives of tropical Africa can increase and multiply in subtropical or moderately warm climates is proved by their increase in the Southern States of North America.

Tropical islands are not in general well adapted for colonization by northern Europeans, for though their climate is more moderate than that of the mainland and tempered by sea breezes, fever often infects the valleys, and the moisture of the atmosphere has a relaxing influence. But many islands not considered wholesome would be far more congenial if proper hygienic measures were taken and the most suitable food and clothing habitually used. The Sandwich Islands are favorable for settlement, and may be compared with tropical highlands of moderate elevation.

The most remarkable instance of the permanent settlement of English people in the tropics is that of the inhabitants of the Barbados and of Tuagua, one of the Bahama Islands. The former are descendants of rebels sent from England for slavery between 1650 and 1700. They have survived through conditions of great misery and severe exposure. The islanders are now chiefly occupied in fishing. Deterioration there has been, but this may fairly be ascribed to poverty and improper food rather than to climate. In Tuagua the people, some of whom belonged to families settled there since the time of Charles II, appear to have maintained somewhat better health and physique.

It is noteworthy how in some circumstances a seemingly small change of climate does harm or good and in others a very great change has no

ill effects. Invigoration immediately follows a change from southern England to the Alps, the Scotch Highlands, Norway, or the open sea; a change for the worse, and loss of vigor overtakes natives of the north of England or of Scotland who fix their abode in the Thames Valley or near cities in the south. On the other hand, English crews may winter in the Arctic regions, where temperature is 60 degrees below what they are accustomed to, and diet coarse and unvarying; yet they maintain perfect health. Food untainted and moderate in quantity and abstinence from alcohol probably have much to do with health maintenance in any climate.

Temperature falls about 1° F. for every 270 feet altitude on the average.[1] Other conditions being equal, a place at 6,000 feet high has a temperature fully 20° lower than the plain at the sea level.

Generally, the range of temperature increases from the equator toward the poles, from the coast toward the interior, and from mountains in the tropics to mountains in northern countries. Humidity is less at high levels, but relative humidity may be greater than at low levels, and saturation may prevail for long periods. In Europe the level of maximum rainfall is about 3,000 to 4,000 feet; in the tropics, also, the lesser mountain ranges have more rain than the highest, and the maximum rainfall is about 6,000 feet. Mountain valleys are less healthy than high plateaus.

The "vital" or lung capacity diminishes from about 266 to 246 cubic inches in the ascent from sea level to 2,000 feet, and the pulse beats faster by fifteen to twenty in the minute. At 2,000 feet the pressure of air on the chest is reduced by over 200 pounds. Since vital capacity is also diminished by high temperature, the hill station can not equal in this respect the temperate climate, but there is reason to believe that the lung capacity increases in course of time so as to be fully equal to its value at the low level. Evaporation from the skin and lungs increase, and digestion and sleep are generally good.

Strength is naturally greater in hill people. Life is hard, and the weaker members perish; the pure air invigorates; the changes of temperature refresh; good water is plentiful; the exertion of climbing and the deep breathing expand the chest and increase the lung capacity; the food is wholesome and not in excess; activity and alertness are generally expected. On the other hand, in high mountain valleys malaria is often found, also goitre, asthma, ophthalmia, inflammation of the lungs, and diseases of the kidneys. Dysentery, acute bronchial catarrh, typhus, albuminaria, and diabetes are rare; also the many zymotic and other diseases more or less dependent on aggregation.

In a period of thirty-four years the mortality of the Dutch-Indian army was, on low ground, 5.27 per cent, on high ground, 3.66 per cent.

[1] The decrease would be less than this—about 1 degree for each 400 feet, up to 1,000 feet.

MENTAL AND PHYSICAL QUALITIES IN RELATION TO CLIMATE.

Distinguished observers[1] maintain that the white man can not flourish in the tropics, and will not work where an inferior race works; that in Ecuador and Brazil the white race dies out in the third generation; that in Southern and Central America, north of Uruguay, the colonies break up through fever and climate; that in Panama and other parts of Central America the air is so pestilential that even the Chinese succumb at an enormous rate, and that the most fertile parts of the earth, which are bound to be the most populous, can not possibly be the homes of the Aryan race, or of any higher race whatsoever. There can be no doubt that mental and bodily qualities are very largely affected by the atmosphere, with its various constitution of density, temperature, moisture, cloudiness, fog, wind, and organic pollution. Extended investigation of the effect of climate upon human health and welfare would lead to results of the highest importance. The inquiry might be directed, in the first place, to an historical examination of the movements of nations, races, tribes, and individuals, and of the effect upon them of change of climate, separating as far as possible the results due to preventable circumstances and change of habits, from results which might be regarded as necessary in the relations of the atmospheric and the human constitution.

Secondly, the fitness of various races for removal to various climates under modern conditions might be examined, and the effects of tropical highlands be compared with those of lowlands.

When we recollect the evil reputation of many localities and climates which in the first half of this century were spoken of as deadly, and when we consider that these have lost their bad name solely by the exercise of local and personal hygiene, we can not despair of the power of man for reducing the unhealthiness even of large areas and tropical climates. Last century a troopship, a prison, and a barrack may each habitually have rivaled the worst tropical country in sickness and mortality; to-day they are as healthy as a country village; the prison, indeed, is a model of salubrity.

The fact has been extensively realized that cultivation and draining may often do for a pestilential tract what cleanliness and ventilation do for an infected building. A scientific inquiry into the results of cultivation, draining, and irrigation in improving or harming the health of districts subject to malaria in various parts of the world would afford information of great value. The nature of the soil, the height of the subsoil water, the microbiology of the soil and of the superincumbent air, and the effect of atmospheric conditions should be tabulated and compared. We already have evidence of the frequent recrudescence of malaria through artificial irrigation in India, and in Egypt

[1] Pearson, National Life and Character, Wiener's Perou et Bolivie. Orton's Andes and Amazon, Curtis's Capitals of South America.

the possibility of the revival of plague through irrigation can not be lost sight of. What malaria means in India is best realized by a glance at the mortality statistics, which show that 3,000,000 natives annually fall victims to this most fatal of all endemic diseases, and we know that where one dies many are enfeebled for life.

Looking at the available evidence, we may fairly infer (1) that the inhabitants of temperate climates are, on the whole, intellectually and physically superior, and that they owe this position largely to atmospheric conditions; (2) that in the tropics and commonly in the temperate zone the inhabitants of the mountains are physically the strongest; (3) that tropical countries are not favorable for rapid permanent colonization by the races of northern Europe and of the Northern States of America; (4) that the maintenance of healthy conditions in persons passing from one kind of climate to another very different climate depends to a great extent on the observance of hygienic method and a change of habit, but also on the time taken to make the move, rapidity of transition being inimical to health; (5) that tribes or races have moved from hot to cold, and cold to hot climates, occupying centuries or thousands of years in their progress, and have not invariably suffered or degenerated, and that therefore, and on other grounds, it is probable that fairly healthy hot or cold countries may in the course of centuries be colonized by races which have successively and slowly occupied lands warmer or colder than their own; (6) that people long subject to extreme variations of temperature, as between winter and summer, and day and night, are better able to colonize than those who are subject to more uniform temperature.

MODE OF ATTACK OF MIASMATIC DISEASES.

It is very desirable that the various diseases which affect the inhabitants of moist countries in the tropics should be traced to their original haunts, and their favorite channel of communication be ascertained. Is the condition known as tropical anaemia mainly a result of temperature or of an emanation from the soil in the air? Are dysentery, diarrhea, hepatitis, and liver disease due mostly to organisms swallowed in food or drink, or inhaled in the air overlying soil rich in organic matter, or are they produced by merely physical properties of the atmosphere acting on imperfectly healthy bodies, by means of over-fatigue, insolation, or chill? It appears likely that both air and water are capable, in the case of several tropical diseases, of conveying the poison. Thus, at Sierra Leone, improved water lowered the death rate, but it still remains high; in the villages of the Najagarrh hills in India, a drain-cut reducing the flood level by 3 feet greatly improved the health of the people, and splenic enlargement cases were reduced to less than one-sixth of their former prevalence; in the canal-irrigated country in India fever is both more prevalent and more virulent, and a great difference in the health of the people is observed between places

where the water level is high and where it is low; the mere neighborhood of a swamp, without any pollution of water supply, is often sufficient to prostrate troops. There can indeed be no doubt that air infected from the ground very commonly causes a widespread epidemic of malaria. When the waters of a flood subside, the fever extends over a wide area and beyond the limits of the flood; and exposure to night air without any other source of contamination is a frequent cause of fever even to the robust. Considering the large number of varieties of bacilli residing in mold and in damp earth covered by sand, the relation of diseases to the air and vapor emanating from the ground is a subject worthy of national or international research.

All over the world there are indications, if not such evidence as amounts to proof, that where the air stagnates or is confined in valleys without exposure to frequent winds, the condition of robust health in a population is not well maintained. In certain valleys of Switzerland, of the Pyrenees, of Derbyshire, in England, and of parts of India goiter and cretinism have been common; in low-lying clay districts in England cancer has been shown to be prevalent above the average, and in limestone or chalk districts to be below the average. Valleys lying across the direction of the prevailing wind and not well ventilated are liable to an excess of heart disease. Whether these effects are in any degree due to stagnant or miasmatic air or wholly to difference in the water supply it is uncertain, and the subject demands inquiry.

Climate has often been credited, even by great writers, with effects on the human constitution which statistics have failed to indicate. Most people have supposed that suicide in England must be most frequent in November or in winter when the dark foggy air depresses the spirits. As a matter of fact, however, in England and in Europe, as a whole, suicides are most frequent in the summer half of the year, and especially in May and June, when the aspect of nature is most cheerful and the air bright and pleasant. A very distinct and considerable rise in suicides, crimes, and nervous diseases takes place in the spring and early summer. The first cold weather in autumn produces a temporary and smaller increase. Montesquieu assumed that the number of suicides is excessive in England, and attributed them to depression, caused by the dark, cold, damp climate. As a matter of fact, the suicides in England are not excessive when compared with France and central Germany, and the climate is not often dark and damp for long periods. Esquirol and Cabanis asserted that a rainy autumn following a dry summer is productive of violent deaths; Vilemais maintains that nine-tenths of suicides happen in rainy and cloudy weather. Quite a different order of things is revealed by a comparison of the figures for suicide, and especially for the suicide of insanity, for the different months. The quick increase of the temperature of the air, the dryness and sunshine of the spring have the effect of precipitating mental alienation and increasing nerve instability; the organism is least robust when the winter passes away.

Suicide predominates in the central part of Europe between latitudes 47 and 57 and longitudes 20 and 40. In the southwest and northeast of Europe the tendency is much less. Italy, Spain, and Portugal have a minimum number. The distribution appears to be little affected by climate, and very largely by mental advance and cultivation, so that the climatic factor, if existent, is concealed. But there is sufficient reason in Europe, at least, to attribute an excess of nervous diseases when other conditions are equal to periodic hot and dry weather and alternations of heat and cold. Countries either very hot or very cold are less subject to suicidal tendencies than the temperate region. But inquiry is needed to dissociate the climatic factor from the many others which confuse the evidence in civilized countries.

The influence of climate upon health and upon national character has never been very fully studied, and is worthy of the attention of Government and of science. The effect of change of climate has already been touched upon in another part of this essay.

The degree of cold which the human body can easily bear is surprising. A temperature of $-70°$ F. with a dry and still air is less trying than a temperature of 20° with damp and strong wind. The present writer has had experience on a mountain in Italy of a temperature of 17° F., with sunshine, which was quite pleasant and not too cold for sitting out. Even invalids can sleep with windows open and sit out, without very heavy clothing, when the thermometer shows several degrees of frost. The purity of the air as well as the dryness seems to invigorate the frame and prevent the sensation of chill. Voyagers in the Arctic regions endure prolonged cold without in any way suffering in health if judicious in their mode of life, and mountaineers are seldom the worse for exposure unless they have greatly fatigued themselves or have been overtaken by rain or snow. The tolerance of heat is also very remarkable where the air is dry and pure and direct sunshine avoided. The temperature of the body rises about 0.05° F. for every increase of 1° F. above the ordinary temperature. The amount of air respired is less in hot than cold climates, in the proportion of 8.157 to 10 ounces of carbon. The total effect of heat and of cold on the human body has never been fully investigated. The net result, however, of a very complex series of changes induced by different temperatures on the inhabitants of different lands seems to show that a moderate or medium temperature is most favorable to health and strength, apart from telluric and constitutional factors, and from diet, training, and habits. Yet there can be no doubt that some race of mankind may attain very great strength and health in any nonmalarious climate.

PART III.—VARIOUS ATMOSPHERIC CONDITIONS AND PHENOMENA.

TEMPERATURE AND HEALTH.

The relation of the temperature of the air to health has already been noted in the case of various diseases. Thus malaria, dysentery, liver diseases, cholera, yellow fever, and dengue belong especially to hot climates. Anæmia and general enfeeblement affect the inhabitants of colder regions when stationed in the tropics. Hot weather in northern Europe increases the prevalence of several diseases, and with drought increases the death rate in towns and damp places. Diarrhea becomes prevalent, and in less degree scarlet fever and diphtheria. Diseases of the intestines increase. Cold, dry, still weather is generally healthy except in towns, and to old people, and to persons whose lungs are delicate. A cold winter in temperate climates increases the death rate, and a mild winter is healthy in northwestern Europe. Influenza, pneumonia, and bronchitis are more fatal in cold weather. Diseases of the circulatory system, heart disease, and phthisis are at their maximum of fatality. Cold, clear, still, frosty weather is, on the whole, healthy and much less fatal in towns than cold with fog.

The most favorable temperature to health in temperate climates is about 55° to 70° on an average; natives of the tropics probably thrive best at a temperature of about 65° to 80°.

DRY CLIMATES AND HEALTH.

A perennially dry air is almost universally favorable to human life, and dryness in a sparsely inhabited and well-watered country is wholesome in several ways, especially, perhaps, in its preventive effect on epidemic and lung diseases. In towns, dry weather without showers is much less favorable, in fact it is distinctly unfavorable. Very damp and rainy countries with moderate temperature are often healthy; for instance, western Ireland, western Scotland, Cornwall, and the lake district of England. The deaths from consumption, etc., are much fewer in these districts than in the drier districts which are more thickly inhabited, though not less, perhaps, than in equally sparsely inhabited drier country districts. That they are so numerous as they are depends probably very much on the tendency to aggregation and bad ventilation in the dwellings in bad weather. Tropical or warm countries, and warm seasons, in many localities, are unwholesome when there has been much rainfall, and this is succeeded by hot weather. Much moisture in a calm air helps greatly to spread various epidemic diseases and malaria. Dry air is favorable to the healing of wounds, and probably to the oxidation or death by desiccation of noxious living matter in the air.

The exemption of many tribes and races living in dry climates from phthisis and other disorders of an infectious nature may be, and

probably is, partly due directly to the dry air which does not permit the growth of the bacillus on solid substances or soil, but must also be attributed to the migratory habits of the people, the outdoor life, and the absence of centers of infection. Arabs, who were exempt from phthisis and scrofula in their camps, died at the rate of 50 per cent when they were located in French prisons. This is only one of many instances which go to prove that the infective matter of consumption clings to solid surfaces and thence invades the human system through confined air.

HEALTH AT HIGH ALTITUDES.

The effect of living at high altitudes has been variously stated, but on the whole it seems probable that most persons become acclimatized to the rarity of the air, diminished pressure, lower temperature, lessened humidity, and increased sun power. Above 6,000 feet the pulse and respiration rates are slightly increased. Dr. Marcet gave as the chief outcome of several years' experiments on the amount of carbon dioxide and air expired at high altitudes the following statements:[1] The effect of altitude and cold combined increases the amount of carbon dioxide expired, but where the cold does not become appreciably greater, as on the Peak of Teneriffe, the amount remains the same as at the sea level. At altitudes above 10,000 feet the amount is lessened. Less air is expired at high altitudes. It appears that the blood more readily acquires oxygen at high altitudes than near the sea level. The body can gradually accommodate itself to altitudes much above 10,000 feet. Recent laboratory experiments by Dr. Loewy showed that the diminution of air density and pressure to about 17.717 inches is well borne, greater rarefaction being balanced by deeper inspiration. A similar compensation occurs when carbon dioxide is added to the air. Animals breathing air rarefied to half an atmosphere eject the same amount of blood from the heart as under normal pressure.

The expansion of the chest and increased action of the heart add to strength and vigor, and the mountain races, with the exception of people living in deep or flat valleys, are generally fine in build. In the tropics, Quito is an example of a large population doing well at a height of 10,000 feet. For some forms of consumption, consumptive tendencies, and several other diseases, such as anæmia, altitude is beneficial; for others, including nervous irritability and heart weakness, it is harmful. The elements which are concerned in these effects have not been identified. For old people and those who can not take much exercise, mountain heights are clearly not well adapted.

SEA AIR AND HEALTH.

Sea air is very beneficial to the great majority of people, and has a wonderful restorative power in many ailments and illnesses. It is free

[1] Proc. Roy. Soc., 1878, 1879.

from all kinds of infective germs, and therefore epidemic diseases are unknown at sea, except in so far as they arise from the material, provisions, or water of the ship, or have been brought on board by crew or passengers. Much of the benefit which would otherwise be derived from a sea voyage is often counteracted by the small space and difficulties of ventilation of sleeping berths and cabins. The temperature of the tropics has a bad effect upon the crew and passengers of ships from colder climates, and loss of weight results; but, in general, the weight and strength of passengers are increased by voyaging in a fair climate. Much depends, of course, upon the accommodation and diet, as well as upon the atmospheric conditions.

THE IMPROVEMENT OF CLIMATE WITH SLIGHT ELEVATION.

From a certain number of experiments and from a review of observations taken by meteorologists of differences between temperature and humidity at different heights above the ground, the present writer came to the following conclusions,[1] shortly stated:

The mean temperature at a height of about 100 feet above the ground does not differ sensibly from the mean temperature at 5 feet, but seems to be slightly in excess.

The means of daily maxima at heights of 69 and 128 feet fall short of the mean maxima at 10 feet, and still more of the maxima at 4 feet. The means of daily minima at the greater heights exceed the mean minima at the smaller heights.

There is a certain altitude, apparently about 150 feet above the ground, at which, while the mean temperature is equal to that at 4 feet, the maxima are lower and the minima higher than at any lower point.

On an average of nineteen months, the mean of maxima was about 1.5° F. lower at 128 feet 10 inches than at 10 feet, and the mean of minima about 0.55° higher.

In cyclones the higher, and in anticyclones the lower, points generally have the lowest mean temperature.

The mean night temperature is always highest at the higher points, and the mean day temperature always lowest.

About sunset in clear or foggy weather, when calm, temperature falls much faster near the ground than at some height above it.

Equality of lower and upper temperature seems to occur about two hours before sunset and after sunrise, but varies with the season.

In clear weather and low fogs, between sunset and sunrise, temperature is always, or nearly always, higher at heights varying from 50 to 300 feet above the ground than at heights from 2 to 22 feet.

In bad weather the higher points are coldest by day and night. In foggy weather, especially with ground or radiation fogs, temperature is very much the lowest near the ground, and within the fog much lower than above it.

[1] Trans. Sanit. Inst. of Great Britain.

The mean daily range at 128 feet approaches closely that of the English seacoast, and at 69 feet is about midway between that of coast and inland stations.

Mean humidity is more than 1° less at 69 and 128 feet than at 10 feet surrounded by trees. Humidity by day is a little greater, by night much less, 2° or 3°.

Places on hills or slopes from 150 to 700 feet above a plain or valley, especially with a southern aspect, have a much smaller annual range, and also a smaller daily range than places on the flat. At 545 feet a superiority of 12° or 13° in the extreme minimum has been registered. Thus we find that at a height about equal to that of the upper rooms of a high house a more equable and drier climate prevails than near the ground, and that conditions on sloping or well-chosen natural elevations are on the whole similar.

The importance to delicate persons, and indeed to the majority of people, of living at some height above the ground, especially in places which are damp, subject to fog, or to unwholesome emanations from the ground, has yet to be appreciated.

EFFECT OF IMPURITIES IN THE AIR OF TOWNS ON MENTAL AND BODILY HEALTH.

A dense population in manufacturing and other large towns is accustomed to breathe a compound mixture in the air which in course of time profoundly affects the health of the race. The oxygen is deficient, the ozone absent, carbon dioxide in excess, hydrocarbons, animal and mineral dust, sulphurous acid, chlorides, ammonia, and microorganisms in pernicious abundance.

The small tenements or crowded rooms produce the high death rate, an enormous proportion of deaths in childhood, and of diseases of the lungs at all ages. The best model dwellings, on the contrary, have a lower death rate than the mean of the town, although the population to the acre is dense.[1] In New York, about twenty-five years ago, 495,000 persons lived in tenement houses and cellars, most of them dark, damp, and unventilated. By hygienic measures, largely by ventilation, the death rate was reduced in twelve years from 1 in 33 to 1 in 38.

Townspeople spend much more of their lives indoors than the peasantry. At their work and in their rooms they breathe dust of many sorts, particles of skin, organic poisons, and often many pathogenic germs which would develop in their bodies if they had not already passed through the specific disorder. The air being deprived of its exhilarating power, they seek stimulants in food and drink, and go to mischievous excess in the consumption of animal flesh and alcohol. Hence many internal diseases. Children are never seen of the right sturdiness and color which is common in the country. Most children

[1] The corrected death rate of infants in the dwellings, chiefly blocks, of the Metropolitan Association for Improving the Dwellings of the Industrious Classes in London, has been for some years past much below the average.

born and bred in the crowded parts of towns are sickly, pale, feeble, unnaturally sharp and wizened, their voices are of bad quality, and their height and weight deficient. The elder people become reckless, often depraved, dirty, and scarcely ever free from ailments. Their whole bodily, mental, and moral nature deteriorates. As a consequence, it is difficult for native townsfolk to obtain employment in competition with immigrants from the country. In general, policemen, laborers, domestic servants, and several other classes of employees are found to be most fitted for their duties if country born, and thus perpetual immigration is stimulated. The best and strongest people are constantly migrating to the great towns, bringing their health and youth to supply the demand for good work, and reducing the death rate, so that the true proportion of victims of town air and town conditions fails to be realized. As a matter of fact, it has been ascertained that very few families survive in central London for more than four generations, and that many die out in two or three generations. A true Londoner of the fifth and even of the fourth generation is rare. A very large proportion, probably the majority, lose the fine stock of health they brought with them from the country within two generations.[1] This is a matter of national and international importance, and the fact should be clearly understood by the public and by legislators that the desertion of the country by the best blood involves the rapid consumption of the finest physical, mental, and moral qualities.

We have, in fact, in our midst areas—climates, if we may so strain the term—of which the properties come into close competition with the influences of the tropics in bringing about the decline and extirpation of families. If the inner circle of a great city were to exclude immigration for a generation, the poverty of its health resources would stare it in the face, and the falling value of a day's labor would startle it into the promotion of hygienic reform. Room and space would be demanded as a necessity for the proper development of human beings.

The rate of mortality is greatly increased by the bad air of towns, and especially by the close, foul air of dwellings and workshops. But the rate of sickness is still more increased above that of the breezy country. In one part of the parish of St. George's-in-the-East, in London, there are nine cases of sickness to one death, but in the worst part of the same district there are twenty known cases of sickness to one death, and a sickness rate of 620 per 1,000. There is, in fact, no good health in the people of the crowded streets, unless it may be for

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[1] Defining a Londoner as one who habitually resides in London, with only few holidays, and whose great-grandparents, grandparents, and parents were Londoners, it is exceedingly difficult to find such a specimen among 5,000,000 people. Even true Londoners of the third generation are very disproportionately small in numbers and feeble in health and strength. These facts, however, do not prove that the inhabitants of large towns must of necessity decay unless recruited from without, for with better homes, houses, more air, reduced hours of work, more holidays, and better hygienic conditions of suburban as compared with central quarters, the prospect of continued vitality greatly improves.

a short time among newcomers from the country. "They are perpetually on the trudge to the hospitals, and get patched up again and again and live on."[1] Much of this most deplorable state of things may be owing to excess of alcoholic drink, but the excess is in many cases the result of a demand for a stimulant which pure air might have prevented. About 1,000,000 out of 4,000,000 persons are treated at London hospitals and dispensaries in a year, and probably this represents fairly well the sickness of great towns in general. A great amount of the lassitude and idleness of the lowest population of cities has been traced by Dr. Richardson to want of ventilation, in their own and former generations. "Tell them," said Mr. Chadwick, the great sanitary reformer, "that when they hear of that disease called consumption they ought to know that it comes constantly from bad administration, which permits dwelling houses to be built on damp and sodden and rotten sites, and which permits industrial workers to breathe, but not to live, in foul airs, gases, vapors, and dusts. Tell them that in model dwellings a death rate of 15 in the 1,000 has replaced one of 30 in the 1,000." Dr. Louis C. Parkes, medical officer for Chelsea, states that much of the anæmia, the pale faces and disordered digestions, and many of the wasting diseases of children in the great towns are to no small extent due to a condition of atmosphere which prevents the perfect action of the lungs and the complete oxygenation of the blood, and so lowers the tone of the body and the ability to repel disease. These facts ought to be impressed upon the population. In England it has been computed that the amount now annually spent on intoxicating liquors might double the actual house room for every family.

The causes of physical degradation in towns are no doubt complex, but that bad air and want of light are very powerful factors, is proved by the following considerations:

Children placed in every respect in equally good conditions in town as they have had in the country, with the exception of the difference of town air, in many cases lose health, grow pale and weak, and in fact do not thrive as they do in the country. Children brought up within the central area of large towns are less robust than children brought up in the country; the children of the poor especially suffer, for though they may have the chance of more flesh meat and often of more food, the air they breathe both without and within doors is inferior, and this affects them not only directly, but indirectly, as through loss of appetite. Very many children in towns have poor and unwholesome appetites. Children in small, crowded towns in various countries, e. g., Italy or Spain, where the streets are narrow and the air foul, often look unhealthy and feeble, and bad air alone, both in town and country, is known to give similar results. Children who are ailing or simply pallid and unhealthy, after the pattern of the alley, very soon gain in health and appearance when moved to country air. The experience of very many adults is similar to that of children, and they rapidly or

[1] Evidence of a doctor in the East End of London.

gradually lose their accustomed vigor during a period of employment in crowded or badly ventilated places. The air of workshops, printing rooms, mills, etc., sometimes changes young, vigorous looking men almost beyond recognition in the course of one or two years. Outdoor work in towns is far less pernicious, and if houses and streets were more spacious, and work places more airy, the physical degradation would be much less perceptible. The mental and moral effect of living in bad air can hardly be estimated, mixed up as it is with the various other conditions which generally accompany it. The wits are certainly dulled when oxygen is wanting and carbonic acid in excess, but social contact tends perhaps more powerfully to sharpen them. Sharpness, cunning, and alertness increase in towns, but great work demanding sustained intellectual effort is not favored, but vitiated, by bad air. In schools, the loss of attention, the difficulty of keeping on long at a task, and the sympathetic weariness, are very frequently the result of bad ventilation. The schoolmaster has great power to improve the quality, or rather the scope, of his pupil's brains by the admission of plenty of air. School-masters and teachers as a class are not in the list of healthy occupations, although they are above the average of strength when they enter their profession. The air they breathe must be concerned in the disorders which especially attack them. Town air seems to tend to weaken the power of the will, the self-command, and the exhilarating sense of freedom and content which distinguish independent yeomen or the peasantry of the hill country, who breathe the vital atmosphere. But here again, we fail to discriminate between the effects of physical and of social differences. Since "self-reverence, self-knowledge, self-control" are among the highest human attributes, and most essential for future progress, the effects, direct and indirect, of vitiated air on character might with advantage form the subject of extended and carefully conducted scientific inquiry.

Intemperance in drink has been commonly attributed to foul air among other influences. There can be no doubt that many a man has become enfeebled by working in bad air, and has taken to drink in the vain hope of keeping up his strength, or with the deliberate intention, for the moment justified, of stimulating his faculties occasionally when they flag. Where the air has so little freshness, mind and body are more likely to crave for artificial and less wholesome sustenance. Whether on the whole the indoor workers consume more alcohol than the outdoor may be doubted, but the effect upon them, beyond question, is worse.

An investigation of the effect of air on mental qualities might be undertaken on the following lines: A number of schools in which ventilation is good to be compared with schools similar in class of scholars, etc., but with bad ventilation of less space, the character of the work and of the scholars to be compared; schools where great improvements in ventilation have been made to be examined as to any notable progress following the improvements; workshops of similar

classes to be compared, respectively good and deficient in ventilation or space, the results as regards health, vigor, intemperance, and efficiency.

WIND FORCE AND HEALTH IN A LARGE TOWN.

In an inquiry made quite recently by the present writer, but hitherto unpublished, concerning the relation between the health of London in winter and the force of the wind, the conclusion was arrived at that on the whole, the mortality is greater in calm than in windy weather, and that there is much less variation in the death rate during the prevalence of strong winds than during the prevalence of gentle winds and calms. The period examined was from November, 1872, to December, 1893. In January, 1890, and in the first quarter of 1892, influenza greatly raised the mortality above the normal, but since this is one of the zymotic diseases, of which the prevalence is increased by calm weather, the figures for these periods have not been omitted. The months of October, November, and December, in 1879 and in 1889, were the least windy periods recorded, and each was followed by a high death rate. Several calm periods coincide with great cold and fog, and it is these in combination which have the worst effect upon health in a smoky town.

Further investigation is required to ascertain which diseases are most apt to spread in calm weather, and the relation of particular winds to particular diseases.

The following table represents roughly and approximately the rates of mortality in the periods mentioned:

Minima, hourly horizontal movement less than 11 miles.

Period.	Death rate.	Death rate in five weeks following.
December, 1873 (22 calm hours, cold and fog)	28.2	23.1
February, 1874 (33 hours calm)	24.6	23.1
November, 1874 (34 calm hours)	27.2	31.4
February, 1875 (no calms)	25.7	23.2
October and November, 1876 (no calms)	21.4	22.4
February, 1878	25.4	24.3
December, 1878 (36 calm hours)	28.1	26.8
October, November, and December, 1879 (131 calm hours)	26.6	31.2
January, 1880	31.2	31.7
November and December, 1885	20.64	22.5
February, 1886	24.9	26.9
January, 1887	21.8	19.3
December, 1888	19.8	23.2
January, 1889	20.3	18.2
November and December, 1889	19.48	28.1
December, 1890	24.7	28.5
Quarter ending April 2, 1892	28.2	....
October, November, and December, 1892	18.5	....
Total	24.42	25.25

Maxima, hourly horizontal movement more than 15 miles.

Period.	Death rate.	Death rate in five weeks following.
November, 1872 (no calms)	22.8	24.5
January, 1873 (37 calm hours)	19.2	24.8
February and March, 1876 (no calm hours)	24.6	23.4
January and February, 1877 (17 calm hours)	21.6	27.6
November, 1877 (no calms)	22.3	25.3
January, 1878 (24 calm hours)	26.6	25.4
November and December, 1880	21.9	25.0
November, 1881	21.18	23.1
November, 1882	21.26	23.5
January, February, and March, 1883	21.9	23.6
November and December, 1883	21.23	20.4
January and February, 1884	21.22	19.9
December, 1884	21.6	23.2
February, 1885	19.6	22.0
December, 1886	20.9	21.8
February and March, 1888	21.2	19.0
February, 1889	18.2	18.6
January, 1890	28.1	21.4
Total	22.15	23.1

DEW AND FROST—EXHALATION OF VAPOR FROM THE EARTH.

From an investigation conducted by the present writer during the two summers 1891 and 1892, the following were among the conclusions arrived at:

Calm or a light air is favorable to dew formation. Wind prevents the deposition of much dew and evaporates much of what is formed. Free radiation or an exposed situation is, on the whole, perhaps the most effectual cause of dew on very many nights of the year. In a level country those parts of a field which are least sheltered by trees and hedges gain most dew on perfectly calm nights. Those parts of any flat substance with the most exposure to the sky are on calm nights most bedewed. The tops of bushes, posts, railings, pans, etc., are on calm nights more bedewed than the sides. Greater cold by greater radiation in these cases produces greater deposition. Radiation from fine points, however, is often not sufficient to counteract in air which is not very humid the effect of the continual impact of air above the dew-point and higher in temperature. Close to the ground the case is generally different, for the movement of air is less and the humidity and cold greater. With fog or a very humid air the points are most bedewed. In dry weather the dew is deposited most on the leeward side, in moist air or fog on the windward side of objects.

Nearly all the conclusions of Wells were confirmed. But a very remarkable amount of evidence soon accumulated from the experiments that a great proportion of the dew formed near the ground is condensed

from vapor derived from the earth. A large quantity of dew was invariably found on clear nights in the interior of closed vessels inverted over grass and sand, very little or none in vessels inverted over plates lying on the ground. The inverted glasses or vessels, however much their rims were embedded in the ground, gave similar results. More dew was found on the lower surface of plates of glass or earthenware or boards slightly raised above the ground than on the upper surface. The lower sides of stones, slates, glass, and paper on the ground were more bedewed than the upper sides. The lower half of stones lying or embedded in sand was more often bedewed and frosted than the upper half. The interior of closed vessels inverted on the grass and covered with two other vessels of badly conducting substance was thickly bedewed, and the grass in the three inclosures was also thickly bedewed. The deposit on the interior of vessels was much less over dry garden earth than over sand or turf. A great deal of dew was deposited on the interior of vessels over dry sand or dust, the earth being somewhat moist an inch or two inches below. Pebbles, etc., lying on a dusty road became quite wet underneath early in the evening, and over grass the underside of a square of glass is clouded soon after the grass loses the sunshine. A very great difference of temperature was found soon after sunset after hot days between the temperature of the soil at a depth of 2 or 3 inches and the temperature of the air close to the ground, just above the blades of grass. On one evening at 11 p. m. the temperature of the exposed grass was 36; of the soil at 15 inches, 60.5.

The author became convinced by these experiments and other considerations, that a great deal of dew comes from vapor from the soil and from plants, and at sea from vapor from the surface of the sea; that malaria and some other diseases are largely caused by emanations from the soil at night bearing organisms into the air, which are then retained by the damp air in a cold stratum near the ground, and that sand overlying damp earth permits air and vapor to rise easily through it. Also, it became evident that a great deal of soil-air may be drawn into houses through pervious soil, and that the neighborhood of damp ground may be thickly infected with organisms contained in the air and vapor which emerge from the soil. A dry covering of sandy earth is not only little impediment to the exhalation of vapor, but may serve to protect microorganisms from the killing action of dry air and sunshine.[1]

EXHALATION OF GASES AND PARTICLES FROM THE EARTH.

It is generally assumed that evaporation or distillation of water gives rise to pure vapor and leaves behind all impurities, but, as a matter of fact, in many natural conditions this is far from being the case. When earth becomes heated, moisture forces its way as a vapor through a

[1] The author has treated this subject more fully in Trans. Sanit. Ins. for 1892: The Exhalation of Vapor from the Earth.

porous superficial layer, and carries with it spores or minute organisms which have multiplied or germinated in the passages through which the vapor passes. A moderate degree of moisture and rather free aeration of the soil are favorable to the growth of many kinds of microbes. We know that cotton wool, unless tightly packed, will not stop the passage of microorganisms; sand and porous soil allow both air and water to pass without depositing all their particulate contents. The filter beds of water companies are efficient not by the action of the sand, but by the retention of particulate bodies in the slimy covering soon deposited above the sand.

Cold nights following hot days seem to favor very much the exhalation of vapor from the earth.

Wind may very likely have an effect in drawing out the gases from the soil, but this action is less important to human health, for malarious germs are dispersed and much less dangerous in windy weather.

Aitken has shown by his experiments on the formation of small, clear spaces in dusty air that bodies warmer than the air drive away dust from their surfaces and create the dust-free black envelope which surrounds them. He further showed that an evaporating surface has a similar influence, and that dust was driven more than twice as far from the wet part of an object as from the dry, the object being above the temperature of the air. The necessary conditions for the repulsive effect to be strongly shown are that the air must be acquiring heat and moisture from the surface. Very little heat with moisture gives a thicker dark plane than double the heat would do. Dust passes through small openings with surprising ease; "any opening which admits air allows the passage of the finest particles." The air contains enormous multitudes of particles so small that the concentrated light of the sun does not reveal them.[1] We may fairly infer from these facts that no inconsiderable part of the fine dust of the air, mineral and organic, is derived from below the surface of the ground. Some interesting experiments made a few years ago showed that the dust deposited in tightly closed cupboards is brought in by the movements of air induced by changes of temperature. Similarly, changes of temperature must draw in and expel fine organic dust from and to air and soil.

The present writer's observations led him to conclude that a great quantity of vapor issues from the earth even in dry weather, and when the surface down to 2 inches or more is dry and dusty that the emission is very large in the evening, but that the maximum appears to take place in the early hours of the morning in dry weather; that soon after sunset in England in summer the temperature of short grass and contiguous air may be 9° to 15° or 20° colder than that of the earth at a depth of 1 to 15 inches, and that about sunrise the temperature of the top grass of a pasture field may be 20° to 30° colder than that of the earth at a depth of 9 to 15 inches and lower, and that the emission of

[1] Formation of clear spaces in dusty air. By John Aitken, Proc. Roy. Soc., 1877.

vapor is very much less through mold than through sand or dust. In hot climates, such as India and Italy, on bare sandy ground and in valleys it seems probable that the differences in temperature between soil and surface air may amount at night to between 30° and 40°, and in malarious places the flow of impure vapor toward the surface may be equal to the evaporation from a marsh. These facts have a very distinct bearing on the generation and prevalence of malaria, diarrhea, dysentery, and other diseases.

Herr Singer, at Munich, found that the maximum temperature of the soil (59.3) at 4 feet 3 inches, was reached on August 24, and Fodor's results gave a maximum temperature at depths between half a meter and 1 meter in August. Liebenberg observed that sand is warmed throughout more rapidly than clay and that the richer a soil in organic matter the greater its power of absorbing heat. Pettenkofer's observations show that a very large amount of air is contained even in firm soils and that effluvia from decomposing organic matter may pass for a long distance through very loose soils. Permeable soils are sandstones, loose sands, and chalk, and are generally healthy unless they contain much organic matter or are superposed upon a clay or other impervious stratum which holds up the water near the surface. Movement of subsoil water of course greatly affects the quantity of earth vapor given off during certain periods. The dried beds of water courses are well adapted for the evolution of malaria, for the superficial layer is usually permeable, the soil contains much organic matter, the water level is not far from the surface, cold air collects over the valley and is often moist and stagnant. In the dry regions of Australia it is well known that water may be found at a little depth below the dry channels of rivers.

Vegetable mold near the surface of the earth is very rich in saprophytic bacteria, and Flugge states that infusions made from manured fields and garden earth contain thousands of bacteria in every drop, though diluted one hundred times. But the observations of the present writer tend to prove that the retention of heat and moisture by this kind of earth is much greater than that of other soils, and that much less emission of vapor takes place from it into the air, so that the organisms which might be expected to invade in excess the air over cultivated ground may in reality be scarcely capable of entering it.

GROUND AIR.

The amount of air in the upper layers of the earth is very considerable, but varies greatly with the nature of the soil. Gravel and sand contain a large quantity of air, which has been estimated at one-third of its bulk. A bird has been experimentally inclosed in a glass cylinder with a solid bed of gravel below and above it, and was not affected, the air which passed through the earth being sufficient to maintain life. The proportion of carbonic acid, however, in some soils, especially

where there is much organic débris, much exceeds that in the atmosphere, and would prevent the success of such an experiment. Ground air passes easily through earth, especially through gravel and sand, so that in the neighborhood of decomposing organic matter houses built on such soil are liable to invasions of poisonous gases. Carbon monoxide has been known to pass 20 or 30 yards through the earth into a house, causing severe illness. But the worst results follow the infamous practice which has been in vogue at the outskirts of large towns of selling turf and gravel on building sites, allowing the excavations to be filled in with rubbish and refuse, and building dwelling houses over these sources of disease. Probably many houses in towns where fever persistently breaks out owe their unwholesomeness to this cause. Even where the soil is natural and undisturbed beneath the foundations, there should always be a layer of impervious material, such as good Portland cement or rock asphalt, between the house and the ground: or else a good space through which the outside air may freely flow. Dwellings well raised above the ground escape many dangers associated with ground air, damp, and drainage. A damp basement is a frequent source of trouble. Hollow skirtings, casings for pipes, bell wires, etc., frequently give opportunities not only to rats and mice, but to deadly gases, to make their way into the apartments.

Inquiry is needed to discover the actual quantities of vapor emitted from different soils and subsoils, at different temperatures of air and soil, at different barometric pressures, at different times of day and night, and at different seasons, and at varying levels of subsoil water. An examination of the different species of microbes or amœba-like organisms emitted would also be of interest.

EMANATION OF ORGANIC PARTICLES FROM EVAPORATING FLUIDS.

The spread of infective organisms into the air from the surface of evaporating liquids is a subject worthy of investigation. It has been generally stated and assumed that an evaporating liquid contaminated with impurities leaves behind it all foreign ingredients and passes into the air as pure vapor. This is very far from being universally true, if evaporation be understood not as a laboratory process carefully conducted, but as a process subject to the various interferences which must occur in natural conditions. Evaporation from the sea may give pure vapor into the air, so long as the sea is tranquil and no bubble breaks on the surface, but the breaking of waves on the ocean and on the shore, and the evolution of gases from animal and vegetable life and organic decay cause evaporation to be accompanied by a considerable emission of sodium chloride, and of other substances in solution, into the air with the bursting of foam and bubbles and the tearing off of spray by the wind.

Marshes give off various gases, especially in the drying process, besides vapor. The upward movement of the air from the drying

ground, the generation of gases in the viscous fluids and in the earth below them, the bursting of countless small bubbles and films, the development of electricity in the evaporation of an impure liquid, the repulsion of small particles by a warm evaporating surface, all help to carry into the lower air a large quantity of microscopic and ultramicroscopic dust. In a research made by the present writer into the diathermancy of thin films of water[1] he was much struck by the force with which the thinnest film snapped; a slightly soapy film of 1½ inches diameter and about one-millionth of an inch in thickness broke with an audible sound. In the viscous fluid of drying marshes there must be millions of thin films breaking and throwing their minute spray into the air which carries off the contained organic particles. Moreover, there must be a continual evolution of very small bubbles of gas from the muddy earth through the liquid above it. The scattering force of small bubbles is surprising. If a glass of effervescing water be watched, the minute bubbles which rise to the surface of the liquid will be seen to throw particles of water to a height of several inches in the air. The smell of drying marshes probably proceeds not only from gases, but from particulate products. Indeed, many organisms and vegetable and animal débris have been actually observed microscopically in the air above marshes. Many living germs are probably beyond the range of visibility. The manner in which spores are scattered from the hyphæ of molds, etc., may represent a similar process in the ejection from marshy surfaces of various microorganisms. The formation of gas bubbles by the *Bacillus coli communis* may be only one example out of many in which such action takes place. This characteristic of coli communis has been used by Klein as a mark of differentiation between it and the bacillus of typhoid.[2]

The influences, or some of them, which have been named as helping to carry small organic particles into the air over marshes may be capable of launching infective matter from the lungs and air passages of persons suffering from such diseases as scarlet fever, measles, diphtheria, and consumption. Certainly organic matter and living particles have been observed in the condensed vapor of breath. Thus walls on which the breath condenses may become culture grounds for disease germs which it contains.

PERMEATION OF BUILDING MATERIALS BY AIR AND VAPOR.

The ordinary materials used for floors of dwelling houses are quite ineffectual to prevent the permeation of gases and microorganisms from the soil into the air of the dwelling. By experiments made with several different materials used for flooring, with a view to determine the rate at which air would pass through them into the Torricellian

[1] Proc. Brit. Association, Cardiff, 1881. Abstract.

[2] Journal of Pathology and Bacteriology, November, 1893; Centralblatt für Bakt. and Parasit., Vol XV, Nos. 8 and 9. Local Government Board Reports, 1892-93.

vacuum over mercury, it was ascertained that mortar is practically merely a coarse sieve and permits the rapid and easy passage of gases, that plaster of paris is also highly permeable, 75 per cent compared with mortar; roman cement permeable to the extent of 25 per cent, and portland and hygienic cement to the extent of about 10 per cent. The rate of diffusion of gases through porous septa is, by Graham's law, in the inverse ratio of the square root of their gravity. If the gases in the earth below the flooring be heavy compared with the air of the room, upward diffusion through the flooring material must be rather slow, unless other apertures for the ingress of outside air are insufficient to supply the draft of fires. When the ground is warm, as in autumn, and contains certain light gases and vapor, there may be considerable aspiration from the ground through the floor into the room. It seems probable that mortar and other porous material would permit the passage or penetration not only of gases, but of microbes, but that good cement would not permit the passage or penetration of microbes to any important extent. Asphalt is still better, and effectually shuts out both gases and germs. Coal gas has been known to pass a considerable distance through the earth under frozen ground and to enter a house through the flooring, and there can be no doubt that much ground air enters houses in this way, especially in autumn and winter. A good concrete layer, 4 to 6 inches thick, or asphalt, under every house would do much to diminish diseases caused by ground air. The reduction of two courses of bricks, which would be saved by diminishing the air space between floor and ground, would partly balance the additional cost.

MECHANICAL VENTILATION IN SCHOOLS.

From a paper by Professor Carnelley on mechanical ventilation in schools, Sir Henry Roscoe drew the following conclusions, briefly summarized:

By mechanical ventilation the microorganisms were reduced to one-tenth, the organic matter to one-seventh, and the carbon dioxide to one-half; the temperature was kept higher without draft, and cold drafts were excluded. In badly ventilated schools microbes increase up to a certain point with increase of wall space; in mechanically ventilated schools the microbes decrease with increase of space. Scrubbing or washing floors had no effect in reducing the emission of microbes into the air, and it was found that the infection of a school with these organisms takes place very gradually, old schools being much more infested than new buildings. Similar facts have been observed by Miquel as regards houses. It is clear that walls and floors and perhaps ceilings also should be faced with an impervious material, adapted for frequent washing, and without interstices. As regards mechanical ventilation, however, it has not yet been proved that proper natural ventilation can advantageously be superseded.

The floors and walls of rooms must often be very suitable culture grounds for the microbes of disease. Many fungi grow upon damp plaster, damp wall paper, the interstices of floors, and upon rough surfaces and ledges in empty and also in occupied rooms. The *Chætonium chartatum*, for example, develops on paper and on the binding and insides of books wherever they are near a damp wall. Paper and size are well adapted to the settlement and multiplication of molds and probably also of some pathogenic microbes.

Bricks, mortar, plaster, and paper are all highly porous, and admit the passage of air continually through them. A common brick can absorb a pound of water, and plaster is also hygroscopic. We have, then, this condition in a room, that it is surrounded by damp, porous material, largely contaminated with organic dust and gases from the interior condensed within the walls and in the flooring or carpets. The resemblance to porous, damp, contaminated ground which is a known source of disease, is sufficiently close to make it highly desirable that better provision should be made (1) against damp in walls, (2) against the penetration of organic vapors and dust into the material of walls and into the interstices of floors, and (3) for the easy cleaning of walls with soap and water, and of floors which should be without interstices, by dry rubbing or with paraffin or otherwise.

AERATION AND SELF-PURIFICATION OF RIVERS.

The oxygen of the air contained in water has been supposed to play an important part in getting rid of the contamination of organic substances and in diminishing the number of pathogenic microbes in the water of streams used for drinking. A large number of experiments have been made in different countries with the object of determining the degree of safety with which water may be used for public supply which has run in the open air for various distances after contamination with sewage and other impurities.

The investigation is by no means a simple problem, and where the bacteria are found to have greatly diminished in number in the course of a few miles, the result is often due to other influences besides aeration, of which gradual dying out of the organisms is one, and sedimentation commonly the most efficient. Frank's experiments on the River Spree, at Berlin, showed that, though in flowing through the city, the river contained hundreds of thousands of bacteria in the cubic centimeter, the water some miles lower contained only 3,000 to 8,000, about the same number as in its upper course. In the Isar, below Munich, the number fell from 15,231 to 2,378 in the course of 22 miles. In the Thames and the Ure, Frankland did not find any considerable diminution. The Massachusetts State Board of Health found in the course of 23 miles a diminution of free ammonia from 1,728 to 1,299, of albuminoid ammonia from 826 to 382, of total nitrogen from 3,000 to 2,156, and

an increase of nitric acid from 218 to 457. Oxidation to an important degree is shown in this case, but the result is not altogether favorable to the efficiency of aeration. In observations made on the River Limmat before and after passing through Zurich the following were the results:

	Distance in kilometers.	Number of bacteria per cubic centimeter.
Outflow from lake	0	225
Station 1	1.86	1,731
Sewer outlets	2.175	296,670
Station 4	2.485	12,870
Station 5	2.796	10,892
Station 6	3.417	5,902
Station 7	5.903	4,218
Station 8	6.214	2,346
Station 9	8.078	2,110

Miquel found in the Seine above Paris a rate of 4,800,000 microbes in the liter; below Paris, 12,800,000; in sewer water, 80,000,000.

Instances of outbreaks of typhoid through the use of river water contaminated miles above the intake are not rare. Gloucester suffered by the poisoning of the river by Kidderminster, 20 miles higher up. A single case of typhoid produced the disease in a Scottish town by the drawing back up the course of the river, owing to the obstruction of a weir, of the sewage which had entered below. At Providence, R. I., an epidemic was caused by the very slight pollution of a large and rather rapid stream 3¼ miles above the intake. When Lowell, Mass., has had a fever outbreak, Lawrence, lower down, has had a similar attack a little later. The Merrimac River has given several instructive examples of typhoid following pollution, and the Schuylkill, which is contaminated many miles above the intake of Philadelphia, appears to be the chief cause of the prevalence of the disease in that city.

Experiments on the artificial aeration of water by the Massachusetts Board of Health, and on natural aeration below Niagara Falls by Professor Leeds, show that little or no diminution of organic particles, and no chemical purification, is brought about.

Dr. Percy Frankland has found that various disease-causing bacilli present no uniformity in their behavior in potable water. Many preserve their vitality for a considerable time—days and weeks—and some, which form spores, for an indefinite time. Gaffkey's typhoid bacillus preserves its vitality even in distilled water for about fourteen days.

Altogether, aeration can not be trusted as effectual in rendering polluted water fit for drinking, and the diminution of organisms which to some extent does take place must be attributed to other causes.

ACTION OF BACTERIA AND OF THE AIR IN CONNECTION WITH DECOMPOSITION AND PLANT GROWTH.

Bacteria, or microbes in general, of an immense number of different kinds are almost ubiquitous on the whole surface of the earth and on all exposed solids. The favorite habitat of most kinds is the moist surface of some substance of organic origin undergoing decomposition. But some sorts appear to flourish on almost any kind of solid exposed to the air. Thus panes of glass, rocks, metals, tiles, and sand will furnish a crop, the richer, no doubt, for any slight deposit from organic liquids or gases. The chief work, and a very vast one, of microorganisms is the transformation of dead organic matter into "inorganic" substances. All the dead vegetable and animal substance lying exposed or where air has access is being transformed into mineral matter by this agency. Decomposition generally consists of oxidation by a class of microbes which take their oxygen from the air, and then the transformation and use of the oxygenized products which sink deeper into the earth by another class of microbes, the anaerobic, which not only themselves detach oxygen from its new compounds, but allow of its being united with products which are formed by chemical changes as a result of their activity. The whole process converts the nitrogenous elements into ammonia, nitrous and nitric acids, carbonic acid and water, and produces also phosphoric acid. It takes place most readily in porous, somewhat moist earth and at a high temperature. It is a necessary preparation of the soil for the life of plants. The active bacteria of this decomposition, nitrification, or mineralization do not extend to any great depth, generally not so deep as 12 feet, below which the ground is sterile. The rapid oxidation going on near the surface leaves little free oxygen for the use of bacteria even at the depth of a few feet. The decomposition effected chiefly by the aerobic bacteria in the upper layers enables plants to draw nutriment from the new products, and thus the presence of air and bacteria in the mold are necessary conditions for the growth of vegetation. These newly discovered facts must have a very important bearing upon agriculture. The relation of air supply, soil, temperature, and moisture to the microbic life in the earth, and consequently to growing crops, will become a fruitful subject of research to chemists, bacteriologists, and scientific farmers.

Most of the diseases of plants are dependent to a very great extent on conditions of weather, and many are transported by the air to new situations where they spread as from a center. Thus they differ from the spreading diseases of animals, which are not, on the whole, mainly affected by the character of a season, and are not carried so far through the atmosphere. The number of plant diseases of an infectious kind, depending on fungi or microbes, is very great. The vine alone is attacked by more than a hundred species. Some species live in alternate generations on different plants; thus the rust of wheat requires

the barberry plant for one of its stages of development. The spores of mildews and microscopic fungi are generally ejected in great numbers and with some force into the air, and are carried from plant to plant, or field to field, by the air, as, for instance, the potato disease, *Peronospora infestans*, and the mildew of the coffee plant. Heat and moisture, dew and gentle rain, are favorable to the growth and spread of most diseases of plants. The fungus of dry rot grows in damp, unventilated places on badly seasoned wood, and when about to produce spores, seeks the light: its sporangia dry up and discharge innumerable spores. The common ferment of grape juice, the *Saccharomyces ellipsoideus*, grows on the surface of the grape, and when it gains access to the fermenting vats develops enormously by budding and division; when its development is hindered, as by drying up of the liquid, spores are formed, which are capable of resisting dryness, high temperature, and various conditions without losing their power of germination. They may thus be carried alive to a new habitat. This action is characteristic of a great number of ferments, of minute fungi, and of microbes generally, and explains the transmission of many diseases both of plants and animals. The globular spore case of mold, such as appears on fruit, jam, bread, etc., scatters its spores in all directions, each spore being about one three-thousandth of an inch in diameter. These float in the air in great numbers. The spores of oidium, again, a vine disease, escape into the air as fine dust, and spread with extreme facility. The sudden appearance of potato disease in a field is due to the field having been sprinkled with the spores of the peronospora in dry weather, and to the quick development of the zoospores when favored by damp, either rain or dew. The smut of corn produces extremely light spores, about one five-thousandth of an inch in diameter; these float in the air, and have so strong a resistent power that they will germinate in water after having been kept for years in a dry place. The peziza of the lily disease fires off ascospores which are carried by the wind to rich soil where they germinate, produce hyphæ, bore into the tissues of the plant, and shed millions of spores around. A disease of the pine is associated also with the groundsel, on which the fungus spends a portion of its existence. The hop mildew is borne by the wind, and has been found to be to some extent averted from threatened fields by thick woods or large hedge rows.

A great deal of disease in plants and forests is produced through wounds, to which the air conveys fungi which accelerate decay. The decomposed organic matter becomes a suitable soil for the development of fungi, which are not parasitic on living parts, and spores from these are very abundant. The hyphæ of the disease fungus follow up the poisonous action of the juices of the mold fungus and spread into the contiguous wood. True wound parasites also alight on the damp surface of a cut or broken branch and extend their mycelium into the living tissues, gradually bringing about the death of the tree.

These and very many other spreading diseases in plants can only with difficulty be controlled when their spores are given off in large numbers, and when the vegetation on which they alight is damp or in a vulnerable condition. Various applications have been tried to save plants, such as potatoes and vines, from attack, and though partially successful, they involve much trouble. The best security is the prevention of the emission of large numbers of the disease spores into the air from decaying or affected plants, and to cultivate only those varieties of plants which are most immune from infection. The extent to which plant diseases are transmissible through the air has never been ascertained. It seems probable that, with the exception of wide-spread disease in exceptional seasons, the diffusive action of the wind would, in general, so disperse the germs as to render them harmless to healthy plants not too near together. If this be so, then the careful destruction of centers of infection as early as possible would very greatly reduce the prevalence and damage of the diseases of plants. The preservation of fruits, such as apples, is only successful where care is taken that they are not too near together, and that those attacked are speedily removed. But in damp, warm places the spread is too rapid for such measures to be effectual. Dry, sterilized air might be found a valuable means of preserving fruits, vegetables, and provisions generally.

INFLUENCE OF WEATHER ON INSECT PESTS.

The effect of a particular kind of season on insect pests is worthy of more attention than it has hitherto received. The importance of attacking in time and as far as possible destroying the insect life which, if neglected, inflicts incalculable damage on crops and gardens, has scarcely been realized, owing to the blight being generally regarded as a necessary evil, not to be foreseen or prevented. The development of insect pests is generally favored by dry weather. Stunting of the growth, and overmaturation of the sap of plants induce early changes in the maturing and structure of aphides; the insects multiply without the interference of the ordinary destructive influences of bad weather, and delicate maggots, etc., which are generally drowned in very large numbers by storms of rain, emerge unharmed. At the same time it may happen that corn and other crops may be enabled by earlier hardening of the case, stalks, etc., to protect themselves against attacks which in wet years would bring serious damage. In some countries, and in respect to some crops, it is customary to arrange the date of maturity with special regard to the protective power of the plant and the period of expected attacks from insects. The whole subject is at present too little under scientific observation, and great benefit might result if the following branches of inquiry were systematically investigated: (1) The influence of different kinds of weather in developing insect pests; (2) the time of appearance of crop insects in different seasons in relation to the weather, and the time at which crops are most

open to attack in different seasons, according to the weather; (3) the treatment of the ground in drought with a view to destroy threatening pests in their early stages, and, in general, the conduct of agricultural operations with regard to the probable development of particular pests resulting from particular kinds of weather; (4) the issue of forecasts of insect prevalence, derived from a careful study of the habits of various species of insect pests, and of the weather of present and previous seasons.

ACTION OF PLANTS ON THE AIR.

Plants in general take up free oxygen from the air and during the night exhale a small quantity of carbon dioxide. They also give a large quantity of oxygen to the air by the breaking up of carbon dioxide into carbon and oxygen through chlorophyll. The oxygen is set free, while the carbon is retained. Experiments have been made on various plants with the object of ascertaining the amount of oxygen which they absorbed at different temperatures. The following are some of the results:

Five seedlings of *Tropæolum majus* absorbed 1.04 cubic centimeters carbon dioxide of oxygen per hour at 35° C.

Four seedlings of wheat absorbed 0.088 cubic centimeter of oxygen per hour at 15.4° C.

Each plant has its temperature of maximum absorption. Wheat evolved 37.6 milligrams of carbon dioxide per hour at 40° C. The maximum amount of carbon dioxide evolved at the temperatures does not correspond with the maximum of oxygen absorbed. Variations in the composition of the atmosphere do not interfere with the respiration of plants, and the relations of the amounts of these gases absorbed and evolved, unless those variations are extreme, and not occurring in natural conditions.

Plants have been placed under glass shades, with their roots immersed in water containing free carbonic acid and certain salts, and with their upper parts exposed to a north light in carbon dioxide, hydrogen, and nitrogen. In the carbon dioxide they did not thrive. Convolvulus throve very well in nitrogen, mixed with a third part of carbon dioxide, and after three weeks these gases were found to be mixed with so much oxygen as to approach the proportions in the atmosphere. The power of plants to produce in a closed space an atmosphere resembling that of the globe might well form the subject of research on a great scale.

THE INFLUENCE OF FORESTS ON CLIMATES.

The influence of forests on climate is now much better ascertained than it was thirty years ago, at any rate with regard to temperate regions. But the importance of preserving trees, woods, and forests is far from being recognized as it ought to be by Governments and by the people generally.

The annual average temperature within forests is slightly lower than in the open. The difference is greatest in summer, least in winter. The day temperature is less, the night temperature more, than in the open. In summer, a beech forest is more effective for cooling than fir or spruce. The soil temperature is lower in forests, especially in summer, when the difference may amount to 14° F. The mean annual relative humidity is from 3½ to 10 per cent greater than in the open. Nearly one-fourth of the rainfall is intercepted by the trees and evaporated or slowly conducted to the ground. Forests somewhat increase rainfall, especially on high ground. The humus formed from fallen leaves diminishes the evaporation from the soil by more than one-half. The whole effect of forests is to retain and more equably distribute the moisture throughout the year, so that streams flowing from them are not torrential, and not subject to heavy floods, but are kept well and moderately supplied. By the prevention of excessive heating of the soil by the sun, and by the diminution of range of daily temperature and of sudden changes, malarious fevers are reduced. The mitigation of strong winds, of hot sunshine, of blizzards, and intense frosts is favorable to health, and generally the shelter and amenity of well-distributed woods, copses, and forest trees are of great hygienic and agricultural importance.

CERTAIN PHYSICAL QUALITIES OF THE ATMOSPHERE.

It is a law of gases that the volume of a given mass is inversely as the pressure; otherwise stated, the density at a constant temperature is proportional to the pressure. The resistance to compression, then, is proportional to the pressure. Yet the law is not exactly true at various pressures and temperatures. Air follows it very closely. Air and nitrogen are, for pressures up to 20 atmospheres at least, more compressed than if this law were exactly true. Amagat, by a fine series of experiments with a tube of mercury extending about 1,000 feet into a deep coal pit, found that air is slightly more compressed up to a pressure of about 80 atmospheres, and then begins to be somewhat less compressed. At about 400 atmospheres the deviation on the side of less compression is nearly one-fifth of the volume, the value pv, or the pressure multiplied into volume, being 1.1897 compared with the original unit. For pressure diminished below that of the normal it appears, so far as experiment has hitherto gone, that the value pv is practically constant down to at least one eight-hundredth of an atmosphere. No determination has been fully verified for pressures below one-thousandth of an atmosphere. The air at a height of 90 miles is still sufficiently dense to set meteors on fire by friction, but can not exert more than one three-thousandth of the ordinary pressure, unless, indeed, the atmosphere be surrounded by some lighter gas. Both air and meteor are at a temperature below −180° C. before contact takes place. The experimental difficulties of ascertaining the values at these low pressures are exceedingly great.

PROPAGATION OF SOUND IN AIR.

The rate of propagation of sound in air is believed, on theoretical grounds, to increase in some slight proportion with the intensity of the sound. The mean velocity of the explosion sounds and air waves of Krakatoa, in the eruption of 1883, was about 700 miles an hour, or less by about 23 miles than the velocity calculated for sound in air at 0° F.; it corresponded with the theoretic velocity at between —20° and —30° F. How was the rate affected by the temperature of the upper air, and what mean value of temperature can be assumed in that total propagation? The rate of movement diminished in the second and third circuits of this great air wave round the globe: the rate for the first passage in one direction was 10.23 per hour; for the last, 9.77 per hour; in the other direction, 10.47 and 10.27, respectively; so that a diminution of rate with diminishing intensity does seem to have occurred. The high temperature of the tropics does not appear to have raised the rate, as might be expected, above the rate in the temperate zones. Nor did the air wave travel faster, so far as can be deduced, than ordinary sound, although, considered as a very low note, it might theoretically be expected to do so. The velocity of the wave in the tropics toward the east was retarded: in the extratropics toward the west was retarded toward the east accelerated; from the data available in the report of the Krakatoa Committee of the Royal Society of London it appears that in the tropics there was an excess of general movement of air from east to west of about 14 miles an hour, and in the extratropics an excess of 14 miles from west to east. Thus the propagation of the air waves throws some light on the mean air movement within and without the tropics. The effect of cold in the regions both of the South and North Poles was not what might have been expected; there was no discoverable retardation by the low temperature. All these results have yet to be interpreted, but may perhaps themselves contribute toward a better knowledge of the laws of the transmission of sound and great waves in air.

The sounds of Krakatoa, which were audible over an area exceeding twice that of Europe, were not very loud in some places in the immediate neighborhood of the volcano. It seems as if the mass of falling ashes, pumice, mud, etc., and the great variations of temperature and humidity in the midst of the hot materials must have exerted a powerful dulling effect. Striæ or laminæ of alternate hot and cold air seem to be very capable of diverting and reflecting sound waves.

With regard to the conveyance of ordinary sounds in air in various kinds of weather, Professor Tyndall and others have arrived at certain results of much scientific interest and practical importance. The condition of the air varies very greatly with regard to transmission of sound, and often without any apparent cause. Fog, rain, hail, and snow do not sensibly diminish sound. The most powerful cause of

stoppage is nonhomogeneity of atmosphere, or aerial reflection by a number of currents, columns, or laminæ of different density. On one day guns and sirens were heard at 10½ miles; two days later were inaudible at 3 miles. Water in the state of vapor mixed with air, in nonhomogeneous parcels, acts powerfully in wasting sounds. Not only clouds, but layers of transparent air, may produce echoes both intense and long. The power of the particles of cloud to produce aubible echoes has been doubted by Tyndall; but we may observe that a grove of trees in leaf, even of larches and pines, has a very strong effect in reflecting sound and in heightening its pitch. Let any passenger by railway note the marked rise of pitch as the train passes between woods of beech or oak. The sound resembles that of a small cascade, or of wind among rustling leaves.

The blasts of the fog siren have hitherto been found to be most effectual of all sounds tried for prolongation, penetration, and small cost. Its audibility is good at a range of 2 miles under all conditions. Experiments are still needed in order to attain a higher efficiency in sound propagation for maritime and other purposes, and to ascertain the effect of air in various conditions. The transmission and collection of sound through a few miles by means of suitable exciters, polished funnels, and acoustic mirrors of large size has not been developed as it might be.

AURORA BOREALIS AND AUSTRALIS.

The aurora borealis or australis is very far from being understood. The height of the luminous arch has been variously estimated and calculated as between 33 and 281 miles, and no doubt greatly varies in different latitudes and in different displays. The greatest height estimated was 500 miles. But in high latitudes the aurora has been observed to emerge from the tops of hills and even as a rule from the ocean, but not from ice floes. Loomis has given much information concerning the distribution of the aurora over the globe in the Smithsonian Report for 1865. Near latitude 40 in the United States only 10 auroræ, on an average, are seen annually. Near latitude 42, about 20; near 45, about 40; and near 50, about 80 are seen. Between latitude 50 and 62 auroræ are seen almost every night, as often to the south as to the north. Farther north they are seldom seen except in the south, and from this point northward they diminish in brilliancy and frequency. Near latitude 78 the number is reduced to 10 annually. In the meridian of St. Petersburg the region of 80 auroras is found between 66° and 75°. The region of greatest auroral action is a zone of oval form encircling the North Pole. This zone resembles a line everywhere perpendicular to a magnetic meridian. In Europe auroræ are much rarer than in North America. Some auroral displays, such as the remarkable one of March 30, 1894, are visible both in Europe and America. It seems that an exhibition around one magnetic pole is often simultaneous with a similar exhibition around the other magnetic pole of the earth.

The aurora appears to be the result of the agitation and vibration of particles of air under the influence of the passage of an electric current, diverging from the magnetic polar regions. The current passes where the resisting power is least, that is, in highly rarefied air, dense air and a vacuum both offering too much resistance to be used for the course of the current. It strongly affects telegraph wires and corresponds with earth currents of uncommon intensity. It has been supposed by Sabine and others to be connected with disturbances in the sun, which, again, depend on the position of the planets. Sun spots and auroræ were considered to be at a maximum in periods of eleven years; auroræ and earth currents to be due to small but rapid changes in the earth's magnetism; the upper conducting strata of the air to behave like a secondary coil, and the sun to act like a primary current which produces magnetic changes in the core of a Ruhmkorff machine. There seems to be no doubt of a connection between the periods of sun spots, of the variation of the magnetic needle, and of auroræ.

Some observers have noted a connection between these lights and great cyclonic storms, but they are certainly not always followed by bad weather, and in North America have been associated with clear skies. Moreover, the height at which they traverse the air renders it unlikely that they should be either the cause or effect of disturbances in the lower air.

Occasionally the elevation of moisture and cirrus cloud to a great height may afford a readier than ordinary means of transit to electric currents. Generally, however, cirrus cloud does not extend to one-tenth of the calculated height of the aurora, and can hardly aid in forming a passage for the current. That some visible effect of induction may be produced on cirrus and high cirro-cumulous, which are themselves electrified, is not improbable. The present writer was once greatly struck by a very extraordinary arrangement of high cirrus and cirro-cumulus clouds in closely packed, detached, reticulated, and nearly rectangular compartments, covering the whole area of the sky overhead, from 9 to 9.50 a. m. on November 17, 1882, in London, and learned afterwards that at about 10 a. m. a great magnetic storm had occurred over the country. The radiant point was about north. The appearance of the clouds was represented on paper at the time, and the diagrams were afterwards submitted to members of the Royal Meteorological Society.

The simultaneous appearance of an aurora in northern Europe and in America rather discounts the supposed connection between this phenomenon and the weather, for changes very rarely take place about the same time and in connection with each other over this wide area. March and October, the months of maximum display, happen to be months which are often windy in England. The cause of the aurora is rather to be sought in changes which come within the scope of astronomical inquiry. The spectroscope has not given much information regarding the nature of the substances which emit the light. The

appearance of the aurora greatly resembles the passage of voltaic electricity through Geissler's exhausted tubes.

Observation is much needed in relation to these matters. The aurora, from a meteorological point of view, is interesting as a proof of the great height to which the atmosphere extends. Estimates of the height of the phenomenon exceeding 100 miles have, however, not been fully verified.

METEORS AND AEROLITES.

Meteors, or shooting stars, are within the domain common to both astronomy and meteorology. The moment they enter the atmosphere they are objects of special interest to the meteorologist. It is known that they traverse the air, where it is dense enough to raise them to a white heat, at very great velocities.

Many calculations have been made of the height of particular meteors which have been observed over a wide stretch of country. The statement by one astronomer many years ago as to the enormous numbers[1] which enter the atmosphere daily has been repeated so often, without confirmation by the actual observation of others, that it would be well to obtain independent values for particular areas on which to base fresh estimates. The majority of shooting stars are probably telescopic objects and of very small dimensions, perhaps not larger than pebbles. Particles weighing only a few grains become visible to the naked eye if they enter the air at a velocity of 40 miles a second. Many nights pass in which, with a clear sky, only a very few shooting stars cross the field of view.

It has been suggested by a distinguished astronomer that meteors or aerolites are the products of terrestrial or lunar volcanoes, which have been shot out to so great a height that they escaped from the retaining power of the earth's gravitation. In remote ages the density of the air and the amount of vapor, and consequently the friction, must have been greater than at present; but meteorology offers no objection to the theory, and the problem of their terrestrial or extraterrestrial origin is rather one for geology to assist in elucidating.

ATMOSPHERIC TIDES.

There can be no doubt that large tidal effects are produced in the atmosphere by the sun and moon, but they are not easily detected, for the barometer only registers the weight of the air and not the height, and the weight of a column of certain height is diminished under the crest of a tidal wave. Practically, however, solar and lunar gravitation and their atmospheric tides have no important influence on weather. Provisionally, the barometric effect of the lunar tide has been calculated from observation to be from 0.003 to 0.004 inch. The interest of the question lies rather in its astronomical bearing. The range or

[1] Four hundred million has been given by one computation.

differences of thickness of the stratum of air through which the heavenly bodies are viewed must be considerably greater at spring tides than at the opposite phases.

THE ZODIACAL LIGHT.

The zodiacal light still remains very much a mystery. It may be a reflection, by a multitude of exceedingly small and light solid particles driven off from the sun, of the solar beams, and, indeed, it seems highly probable that the development of electricity in the chromosphere may be sufficient to propel small particles with much greater force away from the sun than gravitation can exercise in restraining them. When the surface is large compared with the mass, as in the smallest particles larger than molecules, the electric forces need not be disproportionately great to exceed by many times the force of gravitation even of the sun. If the interplanetary spaces be filled with reflecting and nonreflecting motes derived from sun, and moving at a speed much exceeding that of aerolites, we must suppose that our atmosphere is always receiving within its borders multitudes of these particles which are instantly consumed by friction. Moreover, if such emission proceeds continually from the sun, a similar process takes place from the more distant stars, and the whole of recognized space is traversed by small elementary particles traveling at an enormous speed. The phenomena of the tails of comets tend to corroborate this opinion. In fact, considering the immense number of comets in space, it seems impossible that such small particles can be absent. Compared with their extension, their united mass may be very small indeed within the orbits of the planets. Like meteor swarms, they do not apparently affect the motion of comets or of planets. None the less, the part they fill in the economy of the universe may be considerable.

HEIGHT OF THE ATMOSPHERE.

Meteors which have been calculated to pass with ignition through air at a height sometimes as great as 300 miles; auroræ, of which the height has been estimated by careful observation sometimes to exceed 281 miles; and the duration of twilight, with polarizing effects of the sky, giving a height of 198 to 212 miles, agree in showing a much greater altitude for the extension of our atmosphere than was formerly supposed. First 5 and then 45 miles was generally stated as the outside limit. And we have to remember that at this great altitude of about 300 miles the atmosphere is dense enough to produce very palpable effects. It would be a bold proposition to assign a limit to the atmosphere within 1,000 miles.

ATMOSPHERIC DUST AND THE REFLECTION OF LIGHT.

Atmospheric dust, or particles large enough to arrest the movement of light waves, exercise a very important function in the illumination

of the air and sky, which would otherwise be dark except in the direction of the sun, moon, and stars. The beauty of land and sea and of atmospheric effects would be vastly reduced if the reflecting particles were absent, and houses not facing the direct sunshine would be inconveniently dark. Ozone and oxygen molecules, in some state probably of aggregation, are concerned in the reflection of blue rays, so that an elimination of the coarser dust would not entirely darken the atmosphere. A complete removal of reflected rays would slightly diminish the terrestrial warmth derived from the incidence of light rays from the general atmosphere, and slightly increase that derived from the direct rays of the sun. Invisible, or barely visible, vapor particles are probably still more efficacious in producing similar effects.

SUNLIGHT AND THE EARTH'S ATMOSPHERE—ABSORPTION AND REFLECTION.

The light of the sun which reaches the earth has passed through two atmospheres, one of the sun and one of the earth, and each of these atmospheres robs the light emitted from the sun's body of some of its brilliancy and an unequal proportion of color, so that the original color of the sun is modified by the successive subtractions from parts of the spectrum before it reaches our eyes. The sun's atmosphere arrests more blue rays than red, and the light from the middle of the sun's disk is more blue than that which reaches us from the limbs, for it has to traverse less of the solar atmosphere. Prof. S. P. Langley has shown that the effect of the invisible solar atmosphere is so important that its diminution by a third part would cause the temperature of the British Isles to rise above that of the torrid zone. The earth's atmosphere, also, has the effect of scattering many rays, and principally those waves which form the most refrangible end of the visible spectrum and gives the impression of blue. By the use of an exceedingly delicate instrument, at a height of 15,000 feet, Professor Langley was able to show that at this elevation, where nearly one-half of the absorbing mass of the air was got rid of, the ray 60, near D, had grown in brightness in the proportion 2 to 3, that the blue end of the spectrum had grown in intensity out of all proportion to the rest, and that a very great length of invisible spectrum became recognizable beyond the visible rays below the red. The amount of energy in this invisible extension is much less than that of the much shorter visible end. The conclusions to which Professor Langley arrived as the result of his investigations on the solar light was that the sun is blue, that the solar heat is greater than was supposed, and that the total loss by absorption in the atmosphere is nearly double what had been estimated. The sun he calculates to be competent to melt a shell of ice 60 yards thick over the whole earth annually, or to exert 1 horsepower for each square yard of the normally exposed surface. The existence of life on the planet, and especially of the human race, must clearly be dependent

on the capacity of the atmosphere for modifying and absorbing the radiant energy of the sun.

An investigation of the principal elements concerned in arresting and reflecting the sun's rays would yield results of much interest. The absorptive and reflecting capacity of vapor in the free air has not been determined. The power of any constituents of the air, e. g., ozone and ammonia, apart from dust particles, to scatter the rays of light, is not known. The reasons of the variations in radiation from the surface of the earth on different days when the weather continues clear and apparently unaltered have not been fully made out. Much information might be gained by regular observation at two stations, one on the summit of a high mountain and one on the plain below, of the radiation value by day and night, and by comparing the results with the weather, humidity, and any meteorological phenomena which might be connected with them. Thus, for instance, a comparison of the radiation from the stations on two clear days, one dry and the other humid, would give some idea of the effect of invisible vapor in arresting radiation. If true vapor in a dry state is found in the laboratory not to stop heat rays, the inference would have to be made that vapor in the air often exists in a different but still invisible condition.

WINDS AND TEMPERATURE AT GREAT HEIGHTS.

Balloon observations have shown that a variety of currents are often met with in ascending from the earth to 10,000 or 20,000 feet, and also remarkable changes of temperature, not always in the direction of cold. On September 15, 1805, the air near the earth was 82°, and at 23,000 feet was 15°. On July 27, 1850, after passing through a cloud fully 15,000 feet thick, 17.1° was noted at 19,685 feet, and —36.2° at 23,000 feet. On July 17, 1862, at 10,000 feet, 26°; at 15,000 feet, 31°; at 19,000 feet, 42°; then a little below this height only 16°. Thus it seems that the air may be not seldom divided into adjacent masses differing by 26° or more. On March 21, 1863, up to 10,300 feet the wind was east, between 10,300 and 15,400 feet, west; about 15,000 feet, northeast; higher still, southwest, and from 20,600 to 23,000 feet, west. The changes of humidity are also sudden and great. Rain falls sometimes 4,000 feet above falling snow, at 15,000 feet. At 37,000 feet the dryness of the air indicated an "almost entire absence of vapor," yet cirri floated high above this altitude. On July 27, 1850, the balloon passed through about 7,000 feet of ice-cold water particles, and ice needles formed only at —10°. On March 21, 1893, a small balloon with registering apparatus was sent up to a height much greater than any of which there was previous record, and a temperature of —51° C. was recorded at about 45,500 feet; the air at Vaugirard at the time being at 17° C. This very promising experiment of sending recording balloons to great altitudes seems likely to lead to valuable information on the condition of the air up to 50,000 or 60,000 feet in various kinds of weather.

RANGE OF TEMPERATURE AT GREAT HEIGHTS.

Observations by mountaineers on the Andes and in the Himalayas have shown that the difference between night and day temperatures, at heights about 20,000 feet and over, is extraordinarily great, and that changes are very sudden. The interposition of a cloud of ashes from a volcano produced on Chimborazo a fall from 50° to 15° F. in two hours. The effect of the shadows of clouds on the air and clouds below must be very considerable.

ELECTRICITY AT HIGH ALTITUDES.

Electricity is highly developed in the upper regions. The observations carried on for some years at Pikes Peak, Colo., 14.132 feet above the sea, and about 8,000 feet above the plain, proved that snow and hail are always accompanied by electric manifestations. That St. Elmo's fire, or the brush discharge, occurs when the air is damp with rain, snow, or hail, and that the sparks are often almost continuous in storms of snow and hail, the flakes and hailstones being highly electrified.

The appearance of cirrus suggests the shaping of this cloud by electrical forces, and there can be no doubt that the air above 5 or 6 miles is strongly charged with electricity, which has not yet been experimentally accounted for. The origin is generally attributed to evaporation, by which the evaporated water and the water surface take electricities of different signs, and there is some, but not sufficient, experimental ground for the hypothesis. Gases consist of a vast number of molecules which may be considered as separated from each other, and these can receive an electric charge in such a manner as to make the whole mass of a gas so charged electric. The minute particles of water floating in the air, being better conductors, become more highly charged and present comparatively smaller surfaces with a denser charge continually as they grow in size. In fine weather the air is usually positive, in broken weather more often negative. The upper air is considered to be positive and the earth's surface is negative. Electricity increases very rapidly with height; thus Sir W. Thomson found the potential to increase from 23 to 46 volts for a rise of 1 foot. Clouds in showery weather are strongly electrified and the change of sign is often rapid. In showers and thunderstorms streams of sparks run off from the end of an elevated collecting wire, and sometimes from telegraph wires. Valuable information for the forecast of storms and weather generally might be obtained from observation of the electric character and potential of clouds, obtained through instruments near the surface of the earth.

ATMOSPHERIC CURRENTS ABOVE 40,000 FEET.

The observations of extraneous matter in the upper atmosphere after the eruption of Krakatoa, showed that a current from east to west, of hurricane force (80 miles an hour), prevailed in August and September

over the equatorial region, and that a slower movement of the upper air from southwest and west prevailed in autumn over the northern temperate zone. Investigation of the currents of the atmosphere at heights exceeding 40,000 feet is likely to lead to valuable results. Exploring balloons might even show the ultimate possibility of rapid communications between distant places by means of steady upper currents.

PART IV.—SUBJECTS FOR RESEARCH.

The following subjects for research seem likely to yield valuable results in connection with the welfare of man. The bearing of some of the points suggested may be slight or remote, but are not on that account altogether negligible:

The topographical features of different countries in relation to climate and weather, and a comparison of the effect on weather and climate of similar physiographical features and circumstances in different zones and climatic areas.

The influences of forests and cultivation on weather, on humidity, on atmospheric electricity, rainfall, thunderstorms, soil moisture, and the flow of rivers.

The influence of the radiation from different soils and surfaces on climate, as, for instance, of grass compared with fallow, and of sand compared with rock and clay.

The heat received by the soil from the sun in different climates and at different altitudes.

The intensity of solar radiation at different latitudes and altitudes.

The intensity of terrestrial radiation into space by day and night at different altitudes, and the temperature of small objects suspended at high altitudes in sunshine and at night. This might be obtained by exploring balloons.

The temperatures of clouds of different thickness and different character in their upper, lower, and central parts, and at a little distance outside them.

The causes of the down rush and increase of horizontal movement of the air often observed before heavy showers and hailstorms.

The dynamical and thermal consequences of the rising and falling of masses of air.

The action of air in motion, or wind, on calm or stagnant air near their bounding surfaces; the manner in which by friction and by impact masses of air influence other masses whether at rest or in motion, and the effects of the collision of meeting masses of different specific gravity and humidity.

The influence of clouds of various thicknesses and heights on the radiation from the earth's surface.

The nature of the vapor or invisible water screen which often arrests radiation on clear nights.

The capacity of vapor and water of existing in various states in the air, and the reasons for the great differences of state observed, whether as dry or wet fog, mist, haze of several sorts, clouds of many sorts, ice particles and snow crystals of very many different forms, snow flakes of various shapes and sizes, hailstones of various shapes, construction, and sizes, and soft hail, or graupel.

The temperature of fogs and of their bounding edges.

The climatic and geological effects of coverings of ice and snow.

The relation of the temperature of oceans, seas, and lakes to the climate of the neighboring parts.

The variations and ranges of temperature with height in different latitudes and climates.

The extension of soundings of the high atmosphere with thermometers and other instruments by small balloons on the plan recently successful in Paris or at Vaugirard.

The observation by means also of small balloons and recording instruments of temperatures at various heights above the ground in different kinds of weather, say at 2,000, 4,000, 6,000, 8,000, 10,000, 12,000, 14,000, 16,000, 18,000, 20,000, 24,000, and 28,000 feet. Such observations may give very valuable information for the purposes of forecasting, for there is reason to believe that certain kinds of stormy weather are characterized by very great differences between adjacent strata, especially in cold weather and at high altitudes, and that these differences are diagnostic symptoms in many cases. In fine, settled weather the changes are probably much more regular with increase of height.

The absorption, in air, of radiant heat of low refrangibility in different kinds of weather both along horizontal planes and vertically, and obliquely; and the relation of absorption to actual and following weather. The amount of absorption, which might easily be measured by a thermopile and galvanometer directly toward a constant source of heat, or by a bolometer, would be an interesting subject of inquiry in connection with obscure states of vapor and water in the air, and with the forecast of weather.

The loss of heat by drops passing through a known distance of air, both dry and humid, in a certain time. The relation of the rapidity of the loss of heat to the size of the drop, and the difference between the temperatures of the drops and of the air. Similar experiments could be made with ice bullets. The results might elucidate some points in connection with the evaporation and growth of raindrops and with the growth of snowflakes and hailstones. A high tower in frosty weather, or a shot tower, might be convenient for these experiments; or a cliff of sufficient steepness and height.

The effects of the mixture, on a rather large experimental scale, of masses of air of different temperatures, humidities, and electrical states, and of different electrical sign. The resulting humidity, fog formation, and electrical state.

The effects of mixture of invisible steam of different temperatures, of visible steam at different temperatures, and of each of these in different electrical states. The growth of size, and the color, of the steam particles and the effects of absence and presence of much dust or smoke.

The true results of the electrification of jets of steam or cloudy masses, the relation of the size of the deposited vapor particles to the electrification, and the optical effects of various degrees of electrification in air.

The effect of an electric field on the surface tension of drops of water, and the various effects of varying amounts and proximity of the electricity of the charged surface on drops of different sizes. When the electrical field is uniform the surface tension of the drop is only slightly diminished, and the diminution is independent of the size of the drop. Very small drops thus preserve their high surface tension in the neighborhood of an electric field. But when there are a number of charged atoms surrounding the droplets the effect is different; the diminution of surface tension which is brought about varies inversely as the square of the radius of the droplet. The whole subject of the electrification of gases, dry and moist, the electrification of drops of water and their behavior under electrification, and the relation of surface tension in cloud globules and drops to electricity in natural conditions, requires investigation. The "cloudy condensation" of steam, and the optical effects in electrified steam have hitherto led to conflicting inferences, and careful observation has not yet proved a diminution or increase in the size of the water particles or a recombination of dissociated molecules of oxygen and nitrogen. The question is of great interest in many respects, and may have a bearing on thunderstorms, rainfall, evaporation, and chemical problems.

Shortly stated, there are three principal views of the apparent action of electricity on steam. Mr. Aitken believes that the thick condensation, coloration, etc., of a jet of electrified steam is due to the prevention of the coalescence of the very small condensed particles which would occur without electrification. Mr. Bidwell believed that the effects were produced by the conglomeration under electric excitement of particles which would otherwise have evaporated unseen, not becoming large enough to cause visible obstruction of light. These views are related to Lord Rayleigh's discoveries on the behavior of drops under electrification; the drops coalesced when weakly, and repelled each other when strongly electrified.

Prof. Paul Carus holds a very different view, and considers that the condensation effects depend on the action on steam of exceedingly small particles of dust. "One may estimate," he says, "that pure dust-free, unconfined steam at 100° would require a pressure of 10 or more atmospheres to condense it. Add to this dust particles less than 0.000001 centimeter in diameter, and the pressure sinks to 15

centimeters of mercury; in the case of particles of 0.00001 centimeter diameter, to 1 or 2 centimeters of mercury, that is, to pressure increments certainly met with in steam jets. The fact that nuclei of a few hundred molecular diameters are needed is the very feature of these experiments, and explains why smoke and other coarse material is useless, and why the condensation-producing dust must be so highly specialized." Glowing charcoal and red-hot platinum produce effects similar to those of flame, owing, according to Professor Carus, to the escape of clouds of exceedingly minute particles from these objects. "Dust-stimulated condensation differs merely in degree, not in kind, from jet condensation in air," for air always contains fine dust. "Air nominally purified needs only a higher degree of supersaturation to evoke condensation running through the whole gamut of colors." Mr. Bidwell found the following substances active in the condensation of the jet: Air, oxygen, or nitrogen, in which the electrical discharge was occurring; burning and incandescent substances; fumes from phosphorus; hydrochloric acid; sulphuric acid vapor; nitric acid vapor; acetic acid vapor. The following were inactive: Air, etc., in which the electric discharge had ceased for about ten seconds; smoke without fire; bottled phosphorus fumes; ozone, steam, alcohol vapor; formic acid vapor; sulphurous acid. Finding that the effects of a discharge in nitrogen and in oxygen separately were the same as in air, Mr. Bidwell concluded that the action is due in some way to dissociated atoms of nitrogen and of oxygen. Robert Helmholtz suggested such an explanation, having discovered that flames and incandescent substances generally cause dissociation of the molecules of the surrounding air; and Mr. Bidwell hints at the possibility of the necessity of the presence of water, as in so many chemical reactions, to recombine dissociated atoms.

The whole subject is an important one to meteorology and merits a searching and full investigation.

The difference of weight in drops after falling through a measured height in different states of the air, dry and moist, and the relation of loss or increase of weight to size of drop.

The gain or loss in weight of drops similarly let fall, but previously strongly or feebly electrified. These experiments to be tried in saturated and in foggy air.

The increase in weight and bulk of particles and bullets of ice allowed to drop through saturated and foggy air and through misty rain at a low temperature. The ice bullets to be cooled, before falling, down to several degrees below 0° C., and the effect of electrification to be tried.

Similar experiments to be tried in the laboratory; e. g., frozen spheres of water to be rotated rapidly through freezing fog artificially produced in a closed space; the icy spheres and the fog to be electrified, and the gain in weight of the ice sphere to be noted, also the relation of rapidity in rotation and differences of temperature and electric state to the observed increase.

The development of large ice crystals to be attempted in the laboratory, such as sometimes form on the outside of hailstones. Electrification, saturation of air, and great rapidity of movement would seem needful.

The study of the movement of convection currents over a soil or surface heated to various degrees above the temperature of the air. Smoke might to some extent show the manner in which the currents rise and the height to which they reach in continuous streams. The effect of wind, at some height above the surface, in promoting or retarding the unbroken ascent of currents might be observed, in connection with such phenomena as showers, tornadoes, and the formation of cumulus. The effect of a calm above a moving air mass might similarly be shown on a small scale.

The radiation of air and of vapor, separately and together, and mixed in various proportions; also the absorption. Experiment might give information respecting the radiation and absorption of air and vapor in respect of light and of heat in general of various refrangibility.

The radiative and absorptive power of fog or cloud. Experiments might give useful results both in the laboratory and in natural conditions. The effects of dust and smoke mixed with the fog might be observed, and the comparative loss of heat in unit of time by dusty or smoky and dust-free air.

Observations are needed on the geographical distribution of thunderstorms and hailstorms, the influence of mountains, forests, and local winds, and on means of forecast and warning against damage.

The elaboration of plans for the mechanical use of wind power for pumping, irrigation, factories, mills, and traction or propulsion, and for the conversion of wind power into electrical energy. The geographical distribution of wind force, and the areas in which steady, strong winds blow continually or for long periods, need to be ascertained in order to place windmills in economically advantageous positions. The heights above the ground at which wind is strongest should also be ascertained.

Mr. Symons notes that the Hon. R. Abercrombie, in 1875, summed up the results of a study of the oscillations of the barometer in thunderstorms, and concluded that there are two classes of storms in this country—one in which the barometer rises, in the other it falls. The rise is always under the visible storm, and the greatest rise is under the greatest uptake, or ascensional column of air. Dr. Fines, of Perpignan, established a Redier baragraph in 1875, and in a memoir published in 1883 gave reproductions of the traces of several storms. He found that before heavy rain at Perpignan there is usually (1) a decrease of pressure and temperature; (2) with the rain, sudden increase of wind, rapid rise of barometer, and fall of temperature; (3) at the end of the storm rain, reversal of the last three phenomena.

It appears probable that a fall of the barometer before thunder or hail storms may be caused by the increased amount of vapor in the

column of air above it, and the rise, in most cases, is simply explained by the condensation of vapor permitting drier air to flow in, and still more by the existence of a cold, heavy mass of air at some rather high altitude, which, indeed, is one of the main causes of the storm. The barometer may very probably in most thunder or hail storms be acted upon oppositely by the two coexisting conditions, a humid column of ascending air and a descending block of upper air colder than the average of its level. Hence the mercury is either stationary or oscillates within narrow limits. The rise under the ascensional column may also be frequently caused by the rapid ascent of a column of air which takes an appreciable time to expand to the lower density of the upper levels. A study of the temperature and barometric movements before storms of different kinds, and with different winds, might lead to a useful prognosis of the course and character of storms, tornadoes, and heavy rains.

Observations on the rate of change of ocean temperatures at different depths in relation to the temperature of the air and to the influence of currents are needed, and also of the rate of cooling and warming of air currents passing over a sea surface of lower or higher temperature.

Experiment is needed in extension of our knowledge respecting the amount of ground air and gases in various soils, their expansion under variations of atmospheric and ground temperatures, of atmospheric pressure, and of natural processes of decomposition. Smoking or scented substances buried in the ground might afford some useful information. Also, respecting the production of gases by bacteria in the soil, the movements and permeation of ground air or gases through various soils, the emission of microbes into the air at different seasons and hours, and the density of microbes in the air near the ground. Also, respecting the depth in various soils at which organic matter best undergoes harmless decomposition, so as not to give out noxious products to the air to a degree dangerous to health, or offensively, so as not to poison wells, and so as to be of maximum benefit in agriculture. The relations of ground air to the ground water.

The amount of dew derived from the earth, directly, in various temperatures, soils, and circumstances; the amount exhaled by various plants, and the amount of organic matter and microorganic life in dew in particular situations, such as malarious tracts and water courses. The depth from which dew may be derived, as, for instance, the measurement of the depth at which the soil begins to be moist on sandy elevated malarious plateaus, where dew vapor emanates from the ground, but the surface down to several inches is dry.

The discovery of some means of determining the amount of moisture belonging to dew proper and to deposition from very humid air on solids in certain states of the atmosphere.

The emission of solid exceedingly minute particles from wet evaporating and drying earthy and other surfaces at different temperatures

of air and ground. The emission of organic particles from marshes and drying edges of pools, etc.

The amount of organic matter and number of microbes in the air in different situations, hours, and seasons, as, for instance, in malarious valleys and tracts, and on hills and house tops compared with a height of 3 or 4 feet from the ground, on sandy malarious plains on still evenings, in places subject to cholera, diarrhea, and rheumatism, in low meadows and by river banks at sunset in summer, in places some miles to windward and to leeward of great towns, in streets, in old and new houses, in crowded places, in railway cars and in cabins, and in schools.

An investigation of all the phenomena and physics of evaporation from liquid and solid surfaces. The development of electricity, the effects of differences of temperature, of surface tension of slight impurity and slight films of oily matter, the phenomena of the dust-free envelope, and the conditions of evaporation from the human body would be within the scope of the inquiry.

The determination of the resisting power (1) in pure fresh air, and (2) in foul or rebreathed air in a room, of the various microbes concerned in various diseases of an infectious nature. The effect of dryness of air, of sunshine, of the presence of a minute trace of organic matter, of the character of the material, whether mineral or organic, on which they rest. The effect of ozone, of nascent oxygen, and of the vapors of various antiseptic or "disinfecting" substances. The capability of growth of various disease microbes on culture material intended to imitate the organically contaminated walls or rooms, etc., and the discovery of means for preventing such growth and emission into the air of inhabited places. Examination and culture of microbes and experiment on microbes found on walls of closely inhabited rooms. Cultivation of microbes on size used for papering, and on paper, and on plaster. The observation of the number of microbes in air over various kinds of street pavement. Examination of systems by which the air of sewers and drains may be prevented from entering dwelling houses, and of means by which the drain may enter the sewer from underneath, so that the drain may effectually and permanently be sealed by contained water or sewage.

A very interesting branch of research, and one to which little attention has hitherto been paid, is the formation of ice crystals, snow, and hail. In the free atmosphere, beautiful crystals develop themselves in great variety, mostly hexagonal or six-rayed, but some few with three or twelve rays, and some of less regular shape. At least two hundred different shaped crystals have been observed and drawn, many of the most exquisite delicacy and regularity. Often a single shower yields several different species of snow crystals, but generally there is great similarity in the crystals which fall about the same time. The cause of the difference in shape has not been made out, and indeed is not likely to be fully accounted for by any means at our disposal, but the present

writer has been led by many personal observations to the conclusion that the crystals are differently developed according to (1) the amount of dust or nuclei in the air, (2) the electric state, (3) the humidity of the stratum where they have their origin and of the lower strata, and (3) the suddenness or slowness of their growth. He found that in a clear air on a hill crystals on vegetation were clearer, simpler, and more glassy than in the rather foggy neighboring valley; that in the neighborhood (10 miles) of London, where the air was smoky, the crystals on trees were very much more feathery, branching, and opaque, and yielded smoky water on melting. The upper air varies greatly in the amount of contained dust nuclei, in free electricity, and in differences of temperature between strata. A moist southerly wind beating back a cold northeast wind in England generally yields broad, heavy, irregular, conglomerated flakes; a dry gentle wind, with uniform conditions, yields regular crystals, small and thin; a very dry and cold air in the early days of a severe frost sometimes gives showers of pellets of various sizes, roughly hexagonal or polygonal, very dense, thick, opaque, and like a number of superposed plates. In March, and sometimes in April, a soft hail or dense pellets of snow fall in showers with a northeast or north wind, and dry air, the showers alternating with bright sunshine. At great heights in the Alps, the snow in winter is small and powdery; in summer the flakes are much larger.

Hail is often the result of a sudden condensation of very warm, moist air by great reduction of temperature at a great height. The dust nuclei are soon all occupied by moisture condensed upon them, and as the vapor falls to and below saturation point in a high column, it has not sufficient nuclei on which to condense in cloudy form, and precipitation takes place at a great rate, either on the cloud globules or on the snow crystals which fall through from the upper part of the cloud. Since the whole or a great portion of the column of the topmost cloud is below the freezing point, the globules as they come in contact with the falling crystals instantly freeze, and so the crystal grows and falls ever faster, accumulating bands of ice and snowy particles according as the air is clear and saturated, or else densely cloudy, through which it passes. The electric charge being much denser comparatively on a large drop or crystal than on a small one, and the vapor pressure being less, the hailstones grow very quickly, and since they fall rapidly through very thick clouds, they add much ice by mere impact at their base. The radial structure so often observed indicates the origin of the hailstone from a radial snowflake or hexagonal plate. Hailstones of large size are produced in circumstances of great electric disturbance.

Sometimes a hailstone has been found with finely developed hexagonal ice crystals growing like stalactites from a matrix. Possibly the attachment of a flat hexagonal crystal at a certain stage in the fall of the hailstone and the action of electricity in the rapid passage through the air are sufficient to account for these large ice crystals, but they

have not been observed in other conditions in nature. Small, long, clear crystals are formed on vegetation in a clear, moist air by radiation. It would be interesting to endeavor experimentally to produce ice crystals of large size by strong electric charges in saturated air below the freezing point and in rapid motion.

THE BEARING OF ATMOSPHERIC INFLUENCES ON PLANTS.

The connection between atmospheric conditions and the development of plants, especially of staple crops, is strongly realized by every farmer in countries where weather varies from year to year. But the subject is an immense one, and its branches extend in many directions, some of which have been little explored, and most of which have only recently come under systematic scientific inquiry in a few places. Most valuable work on agricultural meteorology has been done in the United States, in France, in Germany, and in England. The Climatology of the United States, by Louis Blodgett, published in 1857; The Signal Service Tables of Rainfall and Temperature Compared with Crop Production; the Compendium of Phenological Observations, by Ihne, in Sweden; the work of Lawes and Gilbert at Rothamsted, in England; Wollney's Researches in Agricultural Physics; Adamson's and Boussongault's various and interesting observations on plants; the great work of Sachs on temperature in connection with plant life; and Hoffman's extensive work in the same field afford an excellent ground for further researches, which ought to be based as far as possible on a common plan and to be both national and international.

As regards temperature, the following points may be considered to have been ascertained with respect certainly to a large number of plants of agricultural value. A particular temperature or a narrow range of temperature within certain limits is required for the quickest germination and most rapid growth of each kind of plant. Growth is retarded in proportion to the deficiency or excess of temperature. For each plant there is a minimum and maximum temperature and a temperature most favorable to growth. The sums of the temperature required for a certain growth of similar plants in two places are in proportion to the sum of the temperatures above zero at the places. Plants in high northern latitudes grow more quickly with the same temperature than the same kinds of plants in lower latitudes. Capability of resisting cold seems to increase with the age of the plant, and plants containing much water seem least capable of resistance. Seeds of northern-grown or mountain-grown plants germinate and develop earlier than similar seeds in warmer situations when both are planted together in the warmer place. There must be a maximum fruit formation and growth for some period of time best adapted to the plant or crop. Blossoming and ripening of certain plants, beets and potatoes, however early sown, coincided with that of the planting which took place when the minimum temperature of germination of the plant had

been exceeded by the ground temperature. This result discourages very early planting. The highest results in Austria-Hungary were obtained from both beet and potato planted on May 1 as against earlier and later dates. When the necessary earth temperature has been reached, then the seeds should be planted.

The observation of ground temperature ought to be a very important branch of agricultural practice. The temperature at depths of 1½ to 3 inches should be taken daily, and in course of time, when observations and experience have been accumulated, and a classification made of the results for various crops, this will become a more useful and trustworthy guide to the farmer than the temperature of the air. The aspect or exposure, and also the character of the ground, have of course to be noted in connection with these inquiries. In dry ground temperature increases in some ratio according to the size of the particles up to a certain point, and then decreases. This holds good for the warm season. Oscillations of temperature follow in a similar relation. In moist ground the temperature also increases, up to certain limits, with the size of the earth particles, and the ground in a crumbly condition is warmer than in a powdery or fine state of division. In the cold season the coarser ground is colder and follows changes of temperature more quickly than the less aerated or firmer ground.

Fine earth can contain more water than coarse earth, but also evaporates more, and allows less water to sink through it. Penetrability and evaporation are frequently inversely related to each other.

Perhaps some results of ground temperature and moisture observations arrived at by the present writer may be here briefly alluded to, though they were on a small scale. When grass or earth is covered over at night by an impermeable material, the moisture from a little below the surface of the earth exhales, but does not escape, and is deposited on the undersurface of the material and on the grass blades. Plants might thus be kept moist, when desirable, by a covering which could be removed at any convenient time in the afternoon and replaced in the evening. Hollows, depressions, and sheltered parts near the hedges are much more bedewed on most nights, excepting the calmest, than fully exposed places, and the intensity of frost and the sun's heating effect a little below the surface is also generally greater—in fact, the daily and annual range of shallow-earth temperature is greater, but all these results depend on the amount of wind at night in the particular district. Dew, though copious under a close covering, is very much below the normal on the earth under loose coverings or under trees. Since moisture combined with frost is often fatal to plants when frost alone is not, it is important to discover the driest and airiest situations for delicate or early vegetables; if frost and fog with calm are probable, but if the climate is subject to frost, fog, and wind, or frost and wind, a more sheltered situation is desirable, according to the nature of the plant, for some suffer more by cutting winds and others

by freezing fog. The southern border, even to some yards' distance, of a thick, high hedge of evergreen, such as holly, is much warmer than other situations, and is most warm on sloping ground. Pasture land, replacing arable, increases the cold due to radiation at night, and also the relative humidity near the ground, for the dew-point is quickly reached over grass. The difference of temperature between the top of moderately long grass (a few inches) and the surface of the earth or bottom of the blades is often very great in the evening and night, 10° or more occasionally, and at 2 inches deep in the ground the temperature of the roots of grass, even in England, may be 26° higher than that of the blades. The temperature close to the surface of the earth under grass rises very quickly immediately after sunrise. The temperature at 15 inches deep was high, 59° to 62°, and nearly uniform in August. These experiments were made on sandy soil, and in the mold of a pasture field.

The relations of the various qualities and conditions of the atmosphere to plant growth in various soils and situations have still to a great extent to be determined. Agriculture depends not only directly, but also indirectly on weather. A certain kind of season has a compound effect on a great number of crops, on each a somewhat different result, and this result has its effect upon the crops of succeeding years. It may be favorable to a weed or to a species of blight, mold, rust, or parasite, as well as to the crop attacked by such pests, and the net gain or loss for the present and future may not be easy to determine. If a particular character of spring is found to have a particular effect, either in hardening a crop for resistance or in developing a pest at some critical time, or in rendering the ground fit for some other crop than one of which the planting seems likely to fail, then valuable results will have been gained. The co-relation of a variety of plants, of birds, of insects, of fungi, with each other, and the relation of each of these to weather and season, have still, for the most part, to be made out. Accurate observations of the times of planting, the times of gathering, and the character of seasons, may render it possible for specialists to inform farmers with a large percentage of success of the best time for their operations in various localities. Weather conditions are exceedingly important in the cutting and carrying of certain crops—hay, for instance, and there must be a particular time of the summer which is most favorable for each district, in view of which grass should be sown and cut, without, of course, any interference with the individual judgment as to the right time, which must vary with the aspect of weather and crop. It would be desirable to use some standard method of obtaining the actual temperature of plants at a little height above the ground, as well as in their roots. The amounts of rainfall and the relation to plant growth in various soils should be systematically recorded. The amount of sunlight and "actinic" energy with relation to various crops has still to be investigated on a large scale; some valuable results have already been obtained.

ABSORPTION AND EMISSION OF WATER FROM THE LEAVES OF PLANTS.

M. Boussingault showed some years ago that plants absorb from the earth and exhale to the air an enormous quantity of water. He calculated that a field of cauliflower, 1 hectare in extent, can emit in twelve hours 20,000 kilograms. M. Deherain states that a young blade of wheat evaporates in one hour a weight of water equal to its own. *Eucalyptus globulus* is supposed to be capable of evaporating eleven times the rainfall of the area which it covers, provided, no doubt, that the rainfall is not excessively large. Oaks are also great evaporators and grow best in wet clay. M. Fautrat, inspector of forests, has found that the quantity of vapor in the air over forests is much greater than in the air over the open country. But exact comparative observations of the amount of water evaporated within and without forest areas in various climates are wanting. Forests have been planted in certain parts of southern France with excellent results in the improvement of health, and malaria has diminished in several instances in consequence of judicious planting. The question of planting in connection with human health is a very important one, and the influence of forests and trees on the steadiness of the water supply makes it very necessary that forests should be carefully guarded by the State in many countries. Vegetation, large or small, should never be hastily destroyed. Trees and hedges are very useful in breaking the force of strong winds, in giving shelter to animals, and promoting the growth of fruit trees and vegetables, and they add greatly to the amenity of the country.

The exact conditions of climate most suitable to each kind of useful crop, tree, or plant, have yet to be determined, though they are in many cases fairly well known. The development and selection of hardy specimens would be aided by trial of the effect of transplanting or obtaining seed from various climates of each species examined. The gradual acclimatization of plants might, under scientific inquiry, be found to be capable of furnishing better results than have hitherto been obtained.

The amount of water collected by trees from the air in misty and damp weather has not been determined, although in some districts, especially where warm, moist winds from the sea prevail, with frequent mist, it must be considerable.

The exact manner in which the spores of dry rot, potato disease, vine diseases, rust, and other plant fungi are conveyed through the air, and how far they may be carried in a potent state through dry and moist air, requires investigation; also the influence of ozone, of sunlight, and of drought upon them when deposited on their host.

The relation of the air supply, air temperature, and moisture to the microbe life in the soil, in connection with the growth of crops, with biological chemistry, with soil emanations, and with diseases.

The assimilation of atmospheric nitrogen by bacilli connected with certain plants; the results of the fermentation; the possible synthesis within the microbe cell of atmospheric nitrogen and nascent hydrogen, resulting in ammonia.

The influence of different kinds of weather in developing insect pests, especially those which are destructive to crops. The cultivation of crops in such a manner as to render them as far as possible proof against such pests, by choice of varieties best adapted for resistance and by planting and maturing them at times least adapted for insect attacks. The issue of forecasts of insect prevalence, derived from systematic study of the habits of noxious insects and of the weather of present and previous seasons.

Experimental investigation of the respiration of plants.

Germination of plants: its dependence on temperature in a great variety of seeds from different localities and latitudes. The influence of temperature of the air on the formation of chlorophyll, and the activity of assimilation and growth in artificial atmospheres differently composed.

The relation of wind to health, as regards force, direction, and duration, and with relation to temperature and moisture. The health of cities as affected by mean horizontal movements per hour and by the number of calms; different periods in the same cities to be compared, and the same periods in different cities. The relation of wind and calm to infectious and malarious diseases, taken separately, and to rheumatism, neuralgia, bronchitis, and colds. The generally better health of towns, villages, and dwellings in high situations; how far owing to difference of soil and how far to difference of climate, especially temperature, daily range, and wind. The comparative healthiness of the upper stories of houses, especially as regards diarrhea, typhoid, rheumatism, malaria, and tuberculosis. The bodily and mental conditions, such as breakdown, fatigue, or depression from overwork, anxiety, or other causes, and all cases of ill health, in which (1) a fine, placid climate and (2) a windy, changeable, moist climate is most beneficial. A comparison of the health and diseases of inhabitants of wild, windy climates, such as those of northern and western Britain, with the health and diseases of the inhabitants of calm, bright climates, if possible not far removed in latitude. A comparison of the health of sailors on board ships with good, airy quarters with the health of the same class of people in the country on shore in about the same latitudes.

MALARIA.

The relation of malaria to various soils, to the aeration of the soil, height of water level, ground respiration, and plant life, with its evaporative power and emission of oxygen. The distance to which malaria can be conveyed over land and sea, and over fresh water, by the air without losing its infective power. The dependence of the vitality of

the organism on moisture in the air, on temperature of the air, on darkness or light. The effect of belts of trees, walls, and muslin screens in breaking its potency. The effect of dried air, as in a room with a fire, in enfeebling the organism and nullifying its power to infect. The effect of ozone and of nascent oxygen upon it, and the effect of antiseptics such as thymol, cinnamon, toluol, and aromatic vapors.

Inquiry into the infective power, if any, of malaria from person to person through the air, a few instances having been recorded.

CHOLERA.

The extent to which cholera may be regarded as endemic in parts of India and other countries, the nature of the soil over which air is infected, the most favorable amount of aeration and moisture of the soil, the atmospheric conditions most favorable to its growth and to its invasion of the air and of persons. The atmospheric conditions most favorable to its extension over Europe and America, and the special precautions needed to prevent the transport of the poison in such conditions. The possibility of a system of international warnings of the prevalence of the epidemic at any centers and of forecasts of seasons or types of weather in connection with its probable spread. The experimental use of some liquid, such as crude petroleum, for blocking the pores of earth where cholera is endemic, and preventing the emission of germs into the air. The effect of cultivation of various moisture absorbing and evaporating plants and trees in endemic areas.

YELLOW FEVER.

The transmissibility of yellow fever through the air from person to person and how far, and its dependence on moisture, temperature, wind, and other conditions of the air. The character of soil and surface on which the microbe develops, the aeration of soil, etc., and the possibility of checking its growth and emission into the air by spraying with petroleum or some viscous disinfectant or antiseptic. Since yellow fever germs seem to be aerobic and to grow largely on surfaces, the treatment of street surfaces, walls, ships, harbors, etc., in this way seems promising.

THE PLAGUE, TYPHUS, TYPHOID, AND PNEUMONIA.

The extent to which the plague, typhus, typhoid, and pneumonia are severally capable of passing through and infecting in outside air, and also confined air. Their dependence on infected soils and surfaces, and on aerated or nonaerated soils; on atmospheric conditions, especially temperature and moisture, and on the seasons. Their dependence on human habits and previous life, whether mostly in bad or in fresh air. The influence of breath poisons on the growth and spread of typhus, and of drain or sewer air and gases on animal and human

vulnerability by typhoid and pneumonia. Cultivation of whatever germs there may be in stinking air from old drains, middens, putrid sink water, etc., and identification of disease germs if possible.

DIPHTHERIA.

Examination of air for detection of the diphtheria bacillus over polluted surfaces of sandy soil, over ash heaps, decaying vegetable and animal matter, and above drain outlets. Relation of the bacillus to atmospheric conditions where it grows on soil, organic matter, dirty floors, or walls, etc.; how far it is aerobic; how far it may pass through air in different conditions, and how much it loses virulence in dry air, in moist air, and in confined and open spaces. Effect of exposure or aeration in causing it to form spores, if any. Effect of sunshine on the bacilli, with and without air; the diphtheritic poison is rapidly weakened by air with sunshine, but only slowly by sunshine alone. Effect of coating a cultivation of diphtheria bacilli with a very thin film of oil or viscous disinfectant, so as to prevent growth and passage into the air. The favorable temperature, a rather low one, the exclusion from light and air, and the presence of certain other organisms furnish useful points of departure for an investigation of climatic and local conditions of prevalence of diphtheria.

SCARLET FEVER, MEASLES, WHOOPING COUGH, INFLUENZA, AND SMALLPOX.

Distance through which each of these diseases has been known to pass in air in various conditions. Experiments especially with respect to vaccine in relation to the conveyance of smallpox through long distances of outer air. Accumulation of experience and new observations on the virulence of the lymph in dry and humid air, and a comparison with the virulence of pathogenic bacilli of different kinds exposed to like surroundings. Dependence of most of these diseases on air in confined and ill-ventilated spaces for effective spread. How far can ventilation, and how far can diffusion of ozone, disinfectants, and various aromatic substances and vapors counteract the infectivity of the germs?

INFECTIOUS, CONTAGIOUS, EPIDEMIC, AND ENDEMIC DISEASES IN GENERAL.

A full investigation into the comparative health of persons living in fairly isolated places, such as islands or institutions having little communication with populous places, would lead to useful results. The occasions of any outbreak of disease could probably be accounted for and the medium of conveyance identified. The degree of human susceptibility to various infections could be much better made out than in ordinary situations. Moreover, those diseases, such as bronchitis, rheumatism, and cancer, which do not seem to depend for the most part on

infection, but on constitutional or atmospheric conditions, could be better accounted for, the possible causes being few. The immunity of children living in several large and very well-managed institutions from the ordinary diseases of children is instructive, and, on the other hand, the frequent prevalence of ophthalmia in pauper schools indicates an effect of bad ventilation upon crowded children of poor vitality. A great sanitary authority demonstrated the enormous fall of mortality following ventilation of crowded places, and another fall following regular daily head-to-foot ablution and insistence on clean clothing.

A comparison of different atmospheric or climatic influences upon similar branches of the same race, through long and short periods. Thus the effect of moving northward to a colder region upon a branch of a race still established in low northern latitudes, and the effect of living at a greater altitude in several different parts of the world might be traced, and the particular elements in climate which produce a change in race characteristic might be to some extent ascertained. The effect of the same climate upon a number of immigrants from different climates; regard to be paid to direct atmospheric action on the constitution and to indirect action through induced change of habits.

An inquiry into the most suitable food for full health and mental efficiency in various climates, and the relation generally of amount and kind of food to climate. How far simple, unvarying food and temperate and active habits and how far a bracing air contribute to the vigor of mountain people.

The effect of sea and mountain air on the majority of civilized people and brain workers; the effect of pure country air on dwellers in large towns; of habitually breathed fresh air on bodily and mental health; and the possibility of greatly increasing the alertness and work power of a nation by better provision for fresh air in schools, offices, factories, workshops, and dwelling houses. The effect of good and bad air respectively upon tendency to alcoholic intemperance. A comparison of well ventilated with badly ventilated schools, and of schools before and after good ventilation, both as regards specific maladies and as regards mental brightness and progress.

The degeneration of the natives of temperate climates when settled in tropical countries, and the grounds for a belief that gradual migration in the course of generations from cold to warm countries may enable them to continue and flourish. The relative capacity of families from Great Britain, from Australia, from the Northern and from the Southern States of America, and from the West Indies of enduring tropical climates, such as those of India and Central Africa. The degree of toleration of hill climates in the tropics by Europeans, and the endurance of families.

How far the diseases of the bowels, liver, etc., which attack settlers from cold climates in the tropics, and how far diseases of the lungs, which attack settlers from the tropics in cold climates, are due to

microorganic infection and the slow or quick poisoning resulting therefrom, or simply to hot and cold air, respectively.

The diseases resulting from chill, both in hot and cold climates, and the means of guarding against it.

The effect of climate, both direct and indirect, upon the tendency to nervous diseases and mental diseases, and upon the tendency to suicide.

The influence of climate, direct and indirect, upon national character. The effect on health of clear, dry, intensely cold calm weather, such as prevails in high latitudes and on high mountains, and the effect of dry, hot climates as distinct from moist. Both hot and cold dry climates seem to be healthy and tolerable. Separation of the malarious disease effects of hot, moist climates from the mere effects of heat and moisture of the air.

An investigation of the causes of the healthiness of cold, wet summers in western Europe, and of the means by which some of their beneficial results may be artificially imitated.

A comparison of the healthiness of the different seasons in the same and different portions of the United States, and of the relation of zymotic and other diseases to the condition of the air, and to the temperature of the soil and of the ground air. The variety of climate and extent of surface of North America, and the great system of the Signal Service make that country peculiarly adapted for such an inquiry.

The reasons of the arrest of certain spreading diseases, such as yellow fever and dengue, by lower temperature.

The climates and qualities of air most beneficial to persons suffering from nervous diseases, nervous irritability, and heart disease. An attempt at a classification of climates most suitable, in most cases, for each kind of malady or ailment, separating as far as possible the purely climatic from the human factors, such as accommodation, food, etc. The elaboration of a complete medical climatology, applicable not only to persons, robust or invalid, but to families and races, with regard to temporary or permanent settlement.

An examination of the conditions under which, in the crowded quarters of large towns, population deteriorates, so as to become in a short time, if not recruited from the country, physically and mentally enfeebled, and in a few generations almost extinct. The part played by the continual breathing of bad air, and by the crippling produced by attacks of various maladies most rife in crowded places and bad air.

Contrasted with country air, town air contains an excess of carbon dioxide, less oxygen, no ozone, many gaseous and solid impurities and vapors and an immensely greater number of motes of the finest dust. The air is also heated by pavements, etc., so as to become less bracing. The parts played by these various factors in diminishing vigor might be to some degree allocated.

The effects, direct or indirect, of daily or constant breathing of vitiated air on the mental powers, the will, self-control, and temperance.

The effects of vitiated air on the mothers of families, their ability to feed their infants, their strength, and the health of their offspring.

The diseases most prevalent during calm and during windy weather, respectively. The comparative wholesomeness of similar houses or streets in the most exposed and most sheltered situations in towns and country.

The normal aeration or permeation of walls and building materials by external air and by internal air with its impurities; the fitness of many porous contaminated substances lining dwelling houses for the growth of pathogenic organisms.

Research and experiment as to the best means of ventilation, natural and mechanical, for various climates.

The elaboration of a scheme of aero-therapeutics, including experiments in oxygenation, etc.

The effect, whether great, slight, or practically nil, of the aeration or exposure to natural oxygen of contaminated water, and also of various pathogenic microbes in rivers, lakes, and ponds or reservoirs.

The cause of milk turning sour in "thundery weather" and an examination of air at such times with regard to its microorganic contents, its putrefactive influence, and its effect not only on milk, but on various animal and vegetable infusions. Certain kinds of fungi or germs which affect milk may be enabled to survive in warm, moist air, when they would be killed by dry air; in that case the "thundery weather" would turn milk sour simply because the air is then commonly warm and moist.

Animal flesh and other provisions do not putrefy or turn bad for a long time in dry and desert air; apparently moisture is necessary in the air for the conveyance of live microbes and for their attack on the substance.

Wounds heal very well and rapidly in the desert, and disease is very rare among wandering tribes; inquiry seems to be needed to ascertain how far this is due to absence of microbic life in the air and on substances to which the air has access.

If some diseases and putrefaction and such changes as occur in milk and organic infusions are owing to presence of microorganic life in the air, then those changes and fermentations should not occur in mid-ocean, where care is taken that only air which has not been in contact with any part of the ship, etc., gains access; for the air on mid-ocean is considered to be practically free from living germs. Experiment might best be made on small islands or exposed rocks, such as Rockall, which may be assumed to be sterilized.

The antiseptic treatment of wounds is now recognized by the greatest surgeons[1] to depend less on the sterilization of the air about wounds than on the sterilization of all objects, including the hands, instruments, bandages, etc.; so that it seems that the open air is practically

[1] See recent addresses of Sir Joseph Lister and others.

harmless to wounds, except, no doubt, in certain unhealthy situations and near the ground. This conviction agrees well with the realization by physiologists and by public health departments of the general rule that epidemics exist through the action of man and not of the atmosphere. "It is in the power of man," in Pasteur's opinion, "to cause the parasitic maladies to disappear from the face of the globe if, as I am convinced, the doctrine of spontaneous generation is a chimera."

The effect (1) of temperature and (2) of moisture in promoting the growth of various kinds of mold, fungi, saccharomycetes, and plant parasites. Ordinary mold seems to grow well at a low temperature, if the moisture be sufficient.

The influence of dry air in weakening various kinds of microbes or fungi in relation to plant and animal diseases. Their growth on various fomites in relation to qualities of the air and to light.

The relation of weather to diseases, not only to those apparently caused by microorganisms, but to a variety of other maladies. A certain climate or a certain kind of weather may give rise to an excess or maximum of a spreading disease by direct influence on the outside growth of a microbe, or by helping to spread the spores or germs, or by increasing the supply of some pabulum, or by effects on wells and water supply, or by affecting the human constitution so as to lay it open to attack, or by producing effects on human conduct which favor the spread of the disease. The contributory factors may be many, remote, or concealed, but such thorough investigation as is possible could hardly fail to give valuable results.

There is generally a main cause in each disease by attacking which much progress is made. The soil temperature in diarrhea and cholera, the dried sputum in consumption, the close air in typhus, have already been thus marked out.

The lesions, or quasi-lesions, by cold and chill, are exceedingly effective in disarming the resistent powers of the body, so as to give opportunity to such diseases as bronchitis, pneumonia, liver and kidney diseases, dysentery, malaria, and many others. The manner in which by clothing and otherwise these consequences of atmospheric variations may be guarded against might well form a subject for research. The rate of cooling of vessels at the blood temperature surrounded by various fabrics would give useful information. Some experiments of Mr. Garrod[1] showed that in a room at about the average annual temperature of the exterior air, when clothes are removed from the human body, the temperature very quickly rises in the axilla to a point 2° higher than before. The blood vessels are of course congested, and colds, etc., are then easily caught. The rise does not take place when the temperature of the room is above 70° F., and increases as the temperature of the air is less.

[1] Proc. Roy. Soc., 1869, No. 112.

A temperature between 30° and 42° seems to be very favorable to chills, etc., possibly owing to the humidity and conductivity of the air being greater than at lower temperatures, to the absence of the sharp, bracing action of frost, and to the greater number and vitality of microbes in the air than at lower temperatures. Dry, cold winds may have a chilling effect equal to a calm, damp air of the same temperature.

With regard to all these matters of air and health, or season and health, a great deal might be done for the prevention of disease by the public issue of forecasts, or monitions, at appropriate times, showing the character of the maladies common at the season, or to be expected, and giving some plain directions. If this were done weekly, it is probable that the number of lives saved would be larger than those saved by the weather forecasts for coast purposes.

EXPLORATION OF THE ATMOSPHERE IN CONNECTION WITH WEATHER FORECASTS AND A MORE EXACT KNOWLEDGE OF ATMOSPHERIC CONDITIONS.

Captive balloons regularly used, weather permitting, at a number of well-distributed stations, would give valuable information in addition to the ordinary items furnished for the purposes of governmental forecasting. Mountain observatories have already been long enough established to give results which show a different distribution of temperature and pressure before different types of weather. But balloons might be fitted with instruments which would show the pressure and temperature at several heights in succession during ascent and descent, and this information would very probably be important in forecasts, if the height attained were sufficient. Balloon ascents have shown the atmosphere to be frequently arranged in blocks or masses of air of very different temperatures within a short distance of each other, and occasionally in an inverse order to that which might be expected from the law of diminution with height. Thus, on July 17, 1862, the thermometer on the earth was 59; at 10,000 feet, 26; at 15,000 feet, 31; at 19,500 feet, 42; but on descent a little below this height, the temperature fell with extraordinary rapidity to 16. Strata much below the freezing point may have a few hundred or thousand feet above them, currents of air at 40 or 42. The variations are often very large and rapid. The greater the height, within the limits of the cirrus cloud at least, the greater apparently are the differences between adjacent strata or masses of air. Irregularity of temperature and humidity distribution must have a considerable influence on the consequent weather, and a series of balloon observations for a term of years at a good number of stations would probably be of very considerable service both for theoretical and practical purposes.

Free balloons for exploration, such as have given good results in France, might be contrived to ascend to some desired height, and then

rapidly to descend, so as to be again available. The hydrogen balloon might, for instance, carry a small vessel containing a substance which would combine with the oxygen and with the vapor of the air at an approximately known and arranged rate; the increased weight of the contents would reverse the ascent at a roughly calculated height, and, except with strong winds, the balloon would descend at no great distance. In calm weather its motion could be watched with a telescope and its approximate height noted. Intelligent persons in towns and villages should previously be instructed to secure the descended balloon and to take readings. Schoolmasters in France have received such instructions.

It is probable that the condition of air immediately preceding tornadoes, cyclones, and blizzards, and thunderstorms or heavy rains would frequently be of sufficiently remarkable character to give ground for generalizations from balloon records by which the advent of these phenomena could be foretold.

ELECTRICITY, CLOUDS, AND RAIN.

The connection of electricity with the formation of rain, snow, and hail requires much fuller investigation than it has yet received, and research in this field is sure to yield interesting results. The upper air is positive, the lower often negative, and the almost invariable necessity for two or more layers of clouds for the production of anything more than misty rain over level ground seems to point to an almost invariable coexistence of oppositely electrified clouds in the formation of heavy rain. Heavy showers and snowstorms always show a large development of free electricity, but of course this may be merely a *consequence* of the agglomeration of the drops, and in no important degree a *cause* of the precipitation. In the heavy clouds of showers there seem to be generally several zones or areas of opposite electricities. The observations on Pikes Peak show the large development of free electricity in the rain, and hail, and snow formed at great altitudes. Howard deduced from Reed's observations that snow and hail unmixed with rain are positive almost without exception. Probably if the snow and hail could have been intercepted in the upper air, it might have been said "without exception." On one occasion, when "a most awful darkness filled the atmosphere" and some rain fell mixed with hail, the positive charge became "as strong as it could possibly be."[1]

Experiment on the electricity of clouds, showers, etc., does not seem to have been continued in recent years, though much might be learned from it in connection with the other conditions of weather. On the other hand, laboratory experiment on the electrification of steam, of smoke, and of small drops has led to most interesting results. An electrified rod, at a few thousand volts, with brush discharge, in a

[1] Phil. Trans., Vols. XXXI, XXXII.

vessel filled with smoke, widened the "dust-free coat" enormously, and the whole box was cleared of smoke. A discharge from a Voss or Wimshurst machine through smoke causes a very rapid aggregation in masses or flakes along the lines of force, and the soot is left on the sides and floor of the vessel. The most effect is produced when the air itself is electrified, but a knob acts less quickly than a point.

A piece of rubbed sealing wax held about a yard distant from a falling water jet broken into small drops causes the drops at once to cease to scatter, and unites them into large drops as of a thunder shower. A cloud of steam turns into "Scotch mist;" a spherule of water amalgamates with a large mass at the first opportunity; if there be the slightest difference in size or in electrification, the repulsion is exchanged for attraction before actual contact. The opposed surfaces come into collision with considerable violence, even when the relative motion of the centers of the masses is small. Surface tension is overcome, and thus violence of contact promotes the coalescence of drops.

The whole subject is of deep interest, not only in connection with the causes of rain and conditions of cloud formation, but with the physics of the atmosphere generally.

OVERCOOLING, ETC.

Other matters deserving fuller investigation than they have yet received, although they have been the subject of valuable memoirs by Dufour, Von Bezold, and others, are the capability of vapor existing in the atmosphere beyond the normal degree of saturation, "overcooling," as it has been termed; and, secondly, the degree of temperature and other conditions in which small drops of water and cloud globules can exist unfrozen. These questions are of great interest both meteorologically and in relation to physics in general.

With regard to the supersaturation of air, this has been proved to be possible in the laboratory to a remarkable degree when dust is absent, but has not yet been proved in the atmosphere. It seems highly probable that occasionally, especially in very moist air, when much rain and cloud has been long continued, or in the intervals between thunder clouds at a great height, there may be spaces of the atmosphere in which dust is so rare and moisture so large that the ordinary point of saturation may be passed. The accumulation upon drops or snowflakes passing through such a space would be heavy.

The latent heat of condensation from vapor upon cold drops of ice has been supposed, owing to its very considerable amount, to make the growth of such drops or hailstones to a large size by deposition from vapor impossible. But rapid passage through cold air may be found to dispose very quickly of the heat thus set free. Experiment is needed on this point.

With regard to the liquidity of droplets below the freezing point, the

fact is fully proved, and clouds and fogs often seem to be still liquid at 12° to 20° F. below the ordinary freezing temperature of large drops. But the degree of cooling which may be borne without freezing, and its dependence upon the size of the globules in the free air, has yet to be determined. Observation of the sun and moon and the diffraction effects in clouds at ascertained heights would be the best available means, short of direct observation at great heights, of fixing the relation of size to congelation at various temperatures.

DISTRIBUTION OF VAPOR CLOUDS.

Experiments with kites and with electrometers have shown that transparent vapor is grouped in masses through the air like visible clouds, but less continuous, and astronomical observations seemed to show a distribution of the atmosphere not only into horizontal strata, but into vertically extended compartments differing greatly from each other. Brief perturbations of polarization, occurring at any hour of the day, have been ascribed to "clouds" of cirrus, etc., too faint to be seen. Recent experiments in the foehn and in other hill and valley winds have shown considerable differences of temperature at intervals of a few minutes. Delicate and sensitive thermometers, hygrometers, and electrometers might well be used for the further discovery of the varying states and divisions of the air in respect of temperature, humidity, and electric state and of the causes of differences.

There is much reason to assume that the atmosphere is divided, like the sea, into many large and small masses of unequal temperature. The great reluctance of waters of different temperatures to mingle, as seen in the neighborhood of Newfoundland and of the Gulf Stream, also at the head of the Lake of Geneva where the Rhone enters, and at the junction of the Rhone and Arve below Geneva, has its counterpart in the atmosphere. It is curious to see a large body of water like the Rhone plunge down toward the bottom of the lake, leaving only floating substances on the surface.

The present author believes that since particles of water in the air a little smaller than those of fine blue haze would be quite invisible, owing to their inability to reflect light, like a soap film a millionth of an inch thick, which is quite invisible, there must be a quantity of water in moist, transparent air which is competent to arrest heat waves by absorption, and is not in the state of vapor. He believes that a theoretical and experimental investigation of the various conditions of vapor and water in the air would lead to interesting and important results. The effect of a thin veil of cirrus, and of a slight, equally distributed haze upon the intensity of solar radiation has been recently investigated at Catania and Casa del Bosco (4,725 feet above the sea). The cirrus was found capable of intercepting 30 per cent of the radiant solar energy. The haze intercepted 23 per cent when the sun was 10

degrees above the horizon, and only 4 per cent when the sun was at an altitude of 50 degrees. When the sky was light blue and cloudless the absorption was greater than when it was deep blue.[1] Of course, these experiments refer to the whole thermal solar energy, and there is at present no record of the varying amounts of absorption of dark heat only, or of the varying loss by radiation from an object on the surface of the earth in different conditions of the unclouded sky.

SOUND IN AIR.

Experiment has still to determine the rate of propagation of sound in air at different temperatures in average atmospheric conditions at those temperatures in different countries; the rate of propagation for intense compared with feeble sounds; the rate for notes of widely different pitch, and what sounds may be most effective at long distances to the ear and to recording instruments. It is conceivable that instruments may be constructed which would enable messages to be sent by the voice or otherwise through long distances of air. Converging lenses of gas have been constructed for focusing sounds, and similar ones might perhaps be utilized if made on a large scale.

The homogeneity and discrepancy or heterogeneity of the atmosphere have been ascertained to be very important in the transmission and arrest of sound waves; it seems frequently to be impossible, with our present knowledge, to distinguish a good from a bad hearing day. The air is often divided, apparently, into laminæ or divisions of different density, humidity, etc., which stops waves of sound and may even reflect them loudly, though transparent. All these points deserve further elucidation, and are of consequence for maritime and military and naval purposes. They may also serve, with other prognostics, for the forecast of weather. The echoing power of clouds of different kinds is not well made out. The practicability of production of sounds in a dense medium, such as air under pressure or in carbonic acid gas, in order to increase its intensity, is worth investigation.

POSITION OF THE PLANETS, SUN SPOTS, AURORÆ, WEATHER, AND CROPS.

Investigation of the reality of connection between the position of the planets, the number and extent of solar spots and prominences, terrestrial magnetic disturbances and auroræ, cycles of weather, and agricultural crops.

AEROLITES.

The number of aerolites, or shooting stars, which enter the atmosphere daily; their size, weight, and any effect they may have on the upper atmosphere. The possibility of any general sky illumination by the passage of small particles, compared to fine dust.

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[1] Rendiconti del Reale Instituto, Lombardo, 1894.

LIMITS OF THE ATMOSPHERE.

The theoretical limits of the atmosphere; whether any portions are being continually lost into space, and gained from space.

ABSORPTION OF THE SPECTRUM.

The absorption and reflection of various portions of the spectrum of the atmosphere, by air and by vapors, at different heights. The connection of radiation and absorption with states of weather and approaching changes; diathermancy and translucency in connection with forecasting. Absorption of several portions of the visible and invisible spectrum in different states of the air.

COMBINED FORECASTING.

An inquiry into and formulation of a plan for a combined system of weather forecasting. In addition to the present schemes and practice of weather forecast as used in Europe and America, it would seem desirable to employ observation of local instruments and phenomena. Trained observers are often able to make a more correct forecast for their district from the appearance of the sky, etc., than they receive from a central office. The training of observers is a necessary preliminary to a much more extended system of observation. The present writer has proved that a great deal of use may be made of a number of different signs taken in combination. Thus the character of a haze, the superposition of currents, the exact character and appearance of clouds and their edges, the length of trail of steam from a locomotive, the color of the sky and sun, and of morning and evening clouds, the radiation from an exposed thermometer, and the size and manner of fall of raindrops, often give a fair prediction of coming weather. These should be used in combination with the reports of barometric and other instrumental readings from the various stations, and in aid of the established system of data used for weather forecasts. Locally observed phenomena, many of them not at present recognized as significant, might, after a certain number of years' observation, have a definite percentage value assigned to each as a prognostic, and the observer, provided with a table of values, might then add up the percentages of all the signs observed on each occasion, and from the total obtain a very fair estimate of probability of coming weather over a district of moderate area. The following table is intended to furnish an example of such a system of local combined forecast, with imaginary figures:

Station: Haslemere, Surrey, England. Time, 9 a. m.

[Probability of rain in thirty-six hours.]

	Per cent.
Upper clouds, cirrus, cirro-cumulus, from west-northwest. Lower clouds, cumulus, from southwest	16
Edges of cirro-cumulus, hard	27
Edges of cumulus, rounded and hard	31

	Per cent.
Motion of cirrus, fast	23
Motion of cumulus, very slow	8
Vertical height of cumulus compared with breadth, great	73
A few waves or close ripples of well defined hard cirrus strata nearly overhead.	84
Length of steam trail, moderate (estimated 90 yards)	52
Color of clouds at dawn, pale yellow	58
Regular or irregular distribution of clouds	(?)
Regularity or variability of temperature and humidity in adjacent strata, etc.	(?)
[Probability of rain in twenty-four hours.]	
Visibility, great	70
Audibility, great	61
Humidity, difference of bulbs, 4 degrees	46
Humidity (increasing or diminishing), diminishing	29
High clouds, increasing	68
Cirrus (straight or tangled), tangled	81
Stars last night, much twinkling	71
Smoke, tending downward	69
Total	877

Probability, rain.

The number of items in the forecast might be much increased with increasing knowledge, and the value of each sign would also increase with continuous exact observation. Moreover, each sign should be studied not as a single item, but as occurring with others, and when considered in relation to others would gain much in value. Thus, visibility is not infrequent in fine dry weather, and also occurs in moist weather, before rain. If observed day after day in fine weather, its value in forecasting is evidently much less than when occurring in somewhat unsettled weather. In fact, each sign has properly a particular value in particular kinds of weather, and the special value has to be ascertained. The length of time during which a certain type of weather has continued is in some proportion to the probability of the ensuing days being of a similar type.

When the total of the various percentages exceeds a certain fixed amount, the probability of bad weather rises to something approaching certainty, and perhaps the probability of fine weather when the amount is minus goes a little further still. When, in addition, the probability announced by the central office from wide data is in the same direction, it becomes justifiable to place reliance on the forecasts for agricultural purposes and general district warnings. It will also eventually be of great use to farmers to have telegraphic information forwarded to districts toward which bad weather is moving, if there is reason to regard the change as more than local when first noticed.

On some Possible Modifications of Climate by Human Agency.[1]

There can be no doubt that some effect upon climate, shown more by physiological influences upon mankind than by instrumental records,

[1] This section is derived from MS. written in 1891, but not in any way published.

has been produced by extensive afforesting or disafforesting, substitution of pasture for arable land, drainage of wet land, and irrigation; but certain means still remain untried which, if undertaken on a large scale, would probably bring about more important changes than any hitherto accomplished, with the exception, perhaps, of the drainage of wide marshy areas like the fens of East Anglia, irrigation works in India, and changes in the irrigated area of the basin of the Nile.

The drainage works of the eastern counties put an end to the once prevailing ague of the low levels, and the cessation of irrigation in parts of the Nile Valley seems to have deprived the plague, which was once a dreaded affliction, of its former power. The substitution of pasture for arable land tends to increase the cold of the lowest atmospheric stratum, and ground fogs are favored by the active radiation of grassy surfaces.

The influence of mountain ranges, even of small elevated tracts, upon surrounding districts in a climate such as that of England has long been recognized, and no traveler can be surprised to find fewer fine days and more rain in the hilly country than on the plain, but some of the less striking geographical conditions which tend to increase or diminish the rainfall or cloudiness of neighboring localities have been little noted and appear to deserve investigation. During a visit in September, 1889, to the coast of Donegal adjoining Slieve League, a mountainous cliff about 1,600 feet high, the summit of the cliff was observed by the author to be much more densely clouded than the vicinity; this characteristic is common to high, somewhat isolated mountains on our western coast. Moreover, the beginning of the cloud formation took place at a distance of fully a quarter of a mile or half a mile to windward of Slieve League, so that the modification of the wind blowing from the sea took place long before the strong upward trend caused on actually reaching the cliff. The air was raised and expanded, and its moisture partially condensed by the pressure in advance, due to the opposing mass, and not, as commonly stated in text-books, by the cold tops causing condensation. Now, a similar effect is produced by ranges much lower than the Donegal coast mountains, and when the wind is sufficiently charged with vapor rain would begin to fall on many occasions at a considerable distance to windward, and would always be greater in annual amount near the hills than in the more distant low country. Such instances occur in the west highlands of Scotland, the west of England, and Wales. The excess of rainfall begins at a little distance to windward of the hills, reaches a maximum a little to windward of the highest altitudes, and declines again toward the low country on the other side. The western coasts of Britain, Norway, Ireland, and Spain and Portugal all have a large rainfall, and, on the whole, the number of days on which rain falls decreases continually from west to east, except where mountain ranges or hills demand a fresh tribute of moisture. Thus, in the west

of Great Britain, among mountains, the average yearly rainfall is from 45 to 150 inches, and in the west, away from the hills, from 30 to 45 inches, while in the eastern counties it is only from 20 to 28 inches. This very large effect is produced by mountains of moderate extent and of average elevation of 2,000 to 3,000 feet. At Bergen, in Norway, the fall is 89 inches; at Coimbra, in the Spanish Peninsula, 118 inches; at Nantes, 51 inches, and at Bayonne 49 inches. In parts of Sweden and Russia it is as low as 15 inches; in France the average is 30 inches; in the plains of Germany and Russia 20 inches.

But the most striking instance of the rain-compelling power of mountains is afforded by the Khasia Hills, situated about 200 miles north of the head of the Bay of Bengal, and only about one-third of the height of the Himalayas. Here the annual rainfall is said to be 600 inches, of which 500 fall in seven months. At 20 miles farther inland, beyond the hills, the annual amount is reduced to 200 inches; at 30 miles to 100 inches; and at Gowahatty, in Assam, to 80 inches. In the more westerly Himalayas, where the southwest monsoon has already been drained of part of its vapor by passing over a tract of dry land and hilly country, the rainfall is only 120 to 140 inches. Similar instances occur in India, e. g., Bombay, on low ground, 75 inches; among the Western Ghauts, at Uttra Mullay, 263 inches; at Poonah, more inland, 24 inches.

In Mauritius, at Cluny, in the vicinity of mountains and exposed to the southeast trade wind flowing from the sea, the rainfall in almost any month is from four to six times greater than at Gros Cailloux, on the northwest coast, only 16 miles distant.

In England the difference between hilly and level districts is well observed in the winter, when the clouds are low, and when precipitation is less due to ascensional currents than to vapor-laden winds. The clouds on rainy days in winter are very frequently between 500 and 1,000 feet above the sea level. The effect of low hills is consequently most marked at this season. Dartmoor, Exmoor, the Chiltern, Cotswold, Derbyshire, Surrey, and Hampshire hills severally raise the observable rainfall above that of the surrounding country. At the head of the valley of Longdendale, near Manchester, nearly 1,000 feet above the sea level, the rainfall in 1859 was 53⅓ inches; on the west side, and just over the summit on the east side, 58½ inches. At Penistone, a few miles farther east, it was 39 inches, and at Sheffield, still farther east, 25 inches. The height of the hills producing this effect is about 1,400 feet. Similarly, the fall varied from 39.1 inches at Rochdale to 67 inches at Blackstone Edge (1,200 feet), 32.25 at the easterly foot of the ridge, and 20 inches at York in 1848. In 1859 a gauge on the westerly side of Loch Ard gave 92 inches, while another near Glenfinlas, farther east, gave only 48 inches. The instances of Slieve League, of Hoy, and of the South Downs show that it is not only mountainous masses, but also mere barriers against the wind from the rainy qaurter which cause precipitation. The air will be equally lifted to

windward whether the obstacle consist of a mountain or of a galvanized iron screen.

SYMONS'S BRITISH RAINFALL.

An examination of the means for fifteen years at a number of stations in England shows that such cases are not isolated. At Saltash, on the southwest side of Dartmoor, the rainfall was 53.87, at Lee Moor (860 feet), on Dartmoor, 68.96, and at Bovey Tracey, east of Dartmoor, on low ground, 46.08. At Clyst Hydon, the mean was only 34.21; at Exeter, 36.61; and at Exmouth, 34.74. Similarly, at Tavistock (316 feet), near the western edge of Dartmoor, the fall was 54.18; while at Tiverton (450 feet), at some distance northeast of Dartmoor, it was 44.35. At Kingsbridge, to the south, where the influence of Dartmoor was not conspicuous, owing to its position with regard to the prevailing winds, only 37.15 was registered. Taunton, protected apparently by the precipitating influence of both Dartmoor and Exmoor, as well as by the nearer Blackdown Hills to the southwest, recorded only 29.75, against Tavistock's 54.18 and Barnstaple's 41.95.

In Sussex we find that the South Downs, mostly 600 to 700 feet high, and the ranges of hills on the southwest border of Surrey, have an appreciable effect, though they do not exceed 800 feet, except at a very few points. Thus, Arundel registered 34.29; the rising ground north of Chichester, 34.90; Petworth, 36 19; Midhurst, 39.65; Fernhurst, 32.19, against 28.41 at Dunsfold, near Godalming, some miles to the northeast of the hills; 26.55 at Weybridge, still farther east, and 26.13 at Greenwich. At Alton, on high ground (496 feet), the fall was 35.58, against 26.73 at Reading. At St. Lawrence, Isle of Wight, and Osborne, the record gave only 31.20 and 29.91, respectively, and the seacoast from the Isle of Wight to Dover has an average of less than 30 inches. On the low ground of the eastern counties, where the air would no longer be forced upward in crossing the land, the amounts diminish to 24.22 at Royston, 23.78 at Peterboro, 22.81 at Cambridge, 22.63 at Ely, and 21.85 at Shoeburyness. But the low hills of Norfolk and Lincoln raise the amount to 28 and 29 inches.

In the Midlands and northern counties the distribution of rain is similar. Thus, while at Sedbergh, Penistone, and Dunford Bridge, the amounts were 55.26, 56.76, and 55.75, stations at a moderate distance eastward of the hills registered as follows: York, 26.93; Doncaster, 27.33; Leeds, 27.70; Sheffield, 35.02; Stockwith, 23.66; Lincoln, 23.83. The rainfall of Carlisle is remarkable, only 30.07, owing to its position to the northeast of the mountains in the same county, where the amounts reach 80 and 100 inches. In the neighborhood of Sheffield the fall varies from 43.26 at 1,100 feet at Redmires to 33.03 at Broomhall, not many miles distant. Buxton, at 989 feet, has 57.14 inches, and Chatsworth, about 20 miles distant, 36.66. Tunstall, a little eastward of the mountains of the North Riding of Yorkshire, has only 28 inches against 55.26 at Sedbergh on their western side.

In Scotland the rainfall of the northern part of Elgin and Nairn, protected by the mountains intervening between it and the west coast, is less than half that of western Sutherland, Inverness-shire, and Skye. Portree, in Skye, has 81.75 against 25.87 at Inverness. The east coast of Scotland, generally, is very much drier than the west, although the large precipitation during east winds tends to counteract the effect which the mountains westward have in reducing its rainfall during the prevalence of the equatorial currents. Great differences in rainfall may exist within a small area; for instance, the rainfall at Perth is only 32.10 and at Ochtertyre 44.17 against 50 at Lochearnhead, and the rainfall at Bothwell Castle is only 29.98 against 115.46 at Ardlui. At Braemar, at the height of 1,114 feet, the rainfall is only 36.50, owing to the great mass of high mountains toward the south and west.

In Ireland the greatest amounts are registered on the southwest and west coasts, and the fall diminishes inland eastward of the mountains, until in the northeast corner the average is only about 30 inches against 60 to 80 in the west.

Among the above instances the most instructive, perhaps, for the present purpose are the records of Midhurst, Petworth, and Arundel, compared with those a little south and north of these stations. It is plain that the action of the long, wall like ridge of the South Downs, not exceeding 600 feet in average height, is sufficient to cause from 5 to 10 inches excess of rain in its immediate neighborhood, the rainfall 20 miles westward and 8 miles southward, being only about five sixths of that which occurs in close proximity to this ridge. Part of the deficiency on the coast must be attributed to the frequent exemption from heavy showers which form over the land, but not over the sea, in summer. The present author has observed this, especially on days with a light westerly or southerly breeze, and has also noted the preference of thunderstorms for the low ground between the hills and the downs. The greatest fall takes place at Midhurst, which lies about 5 miles north of the South Downs, and at the foot of the southern slope of a second ridge, Henley Hill, about 600 feet high, which stretches from east to west. Compared with Dunsfold, about 17 miles to the northeast, the amount is in the proportion of 4 to 3. Dunsfold is probably deprived of a good deal of rain by the mass of Blackdown (900 feet) 8 miles to the south. Fernhurst, near a cleft or dale in some high hills on its northern side and 2 miles north of Henley Hill, has, roughly, 7½ inches less than Midhurst. That even lower hills (400 feet) in a flat country may raise the rainfall of their climate by 5 or 6 inches is shown by the records of the high ground of Norfolk and Lincolnshire.

Now, the practical inference from these statistics is that it may be possible where desirable to imitate natural barriers on a small scale and to increase rainfall in their proximity in order to diminish it elsewhere. Thus, if between Chichester and Arundel the natural height of the Downs were to be raised by 300 feet, the rainfall would be

increased a mile or so southward and perhaps a few miles northward, but would be diminished over the northern half of Sussex, and probably in Surrey, to an appreciable degree.

Similarly, a wall of 400 feet in height between Yes Tor and Hartland Point, in Devonshire, would increase precipitation along a band parallel with the wall, but would give a drier climate to the more easterly portions of the county, and probably also to Somersetshire. In England, not only does the greatest quantity of rain reach us from the southwesterly quarter, but the clouds are lowest in the rains from that quarter, so that the greatest effect of a barrier is produced on rains coming from south and southwest.

The method of construction is a question for engineers. Would it be possible to construct a screen several hundred feet high, of iron, as used in the large gasometers which we see in the neighborhood of our large towns? Or is masonry necessary in order to withstand the extreme possible pressure of strong winds?

The desirability of forming any such artificial barrier would, of course, depend on the calculated probable benefit to be conferred on any county or district, and it would very likely be only in rare cases that the increased geniality of climate would repay the outlay. Possibly it is only worth considering in the case of very wet climates, or of places where little rain falls and more is needed. In England, supposing for a moment that its erection is desirable, the line to be taken for a wall must be such that there would be very little disturbance of natural features of interest or beauty; in fact, it should either be across barren moors or wastes, or else parallel to the cliffs on a desolate coast. The line above suggested from Yes Tor, near Okehampton, toward Hartland Point, appears in all respects a favorable one for the purpose, as the country to be crossed is dreary and almost uninhabited. The wall would have an additional advantage of permitting trees to be planted on its northeast side in a broad belt, so as to make the beginning of a forest, where the winds are now too severe for vegetation. Another favorable stretch of country lies along the ridge of the South Downs between Swanage and Bridport. A high barrier here would give to a large part of Dorsetshire and southeast Wiltshire a climate not unlike that of Bournemouth, which owes its dryness to the hilly promontory of the Isle of Purbeck.

Portsdown Hill, which runs east and west for nearly 7 miles, and is over 400 feet high, would be another highly favorable ridge for an experimental wall, say 400 feet in height. The practicability of works of this kind can hardly be questioned when we hear of structures like the reservoir embankment at Bombay, a stone barrier 118 feet thick, over 100 feet high, and 2 miles long. A less amount of material would have gone toward a wind wall 30 feet thick at the base, 300 feet high, and 3 or 4 miles long.

A wall 300 or 400 feet in height and 5 or 6 miles in length, extending

from near the Thames a few miles east of London in a northwest direction, would probably have the effect of stopping a considerable amount of fog, which often moves from the Essex marshes toward the metropolis. It would somewhat increase the annual rainfall on its westerly side. A wall stretching from northwest to southeast across some of the heaths in the neighborhood of Woking would reduce the rainfall of northeast Surrey and of London.

The effect of a wall, like that of a perpendicular cliff, would be to drive the impinging air vertically upward, so that the increased rainfall would take place near the wall and a little to leeward.

Experimental barriers might be first erected across the mouths of valleys open toward the west or southwest, for in many such situations a wall 1 or 2 miles long and 500 or 600 feet high would cause increased precipitation near the ocean, and a considerably drier climate in nearly the whole of the remainder of the valley. For example, a wall across the valley, a little to the north of the town of Neath, would reduce the rainfall of the Vale of Neath for a long distance, and many of the Welsh valleys opening westward to Cardigan Bay might be equally protected from excessive winter rains.

With regard to other countries, there are localities where a structure a few miles long based on rocks or ridges already some hundred feet above the sea would prove very beneficial in reducing rainfall farther inland. In other exceptional cases, where precipitation is deficient, it might be promoted on the windward side by similar means.

In parts of Australia, local rainfall might be appreciably increased by raising the height of ridges. Wherever water is scarce and valuable and the climatic conditions favorable, experimental barriers would give interesting results.

Some American cities are very liable to be attacked and partially destroyed by violent tornadoes or whirlwinds. These storms usually proceed from about the same direction, and it might possibly be an experiment worth making to set up a wall, say 300 feet high and 2 miles long, on the dangerous quarter, with the object of breaking their force. The clearing of forests seems to favor the development and progress of American tornadoes by allowing the surface of the earth to become more highly heated and by reducing friction, for they are caused chiefly by the breaking of unstable equilibrium when the lowest strata are highly heated and a cold current prevails within a few miles of the earth's surface.

THE AIR OF TOWNS.

By Dr. J. B. Cohen.

[These Lectures were submitted by Dr. J. B. Cohen, of Yorkshire College, Leeds, England, in the Hodgkins Fund prize competition of the Smithsonian Institution.]

Lecture 1.—Close Rooms.

Perhaps I ought first to explain my reason for selecting for these four lectures the subject of "Town air," a subject which, if it can not be characterized by the word *dry*, certainly does not sound attractive. My reasons are threefold—its importance to health, a personal interest in the subject, and a desire to arouse the same interest in others.

I wish that I could paint for you my ideal city of Leeds—a smokeless atmosphere through which the sun, when he did shine, would shine with his full brilliancy, wide streets interrupted by open spaces with green turf, trees, and flower beds, and a little ornamental relief to the dead monotony of our brick walls.

I am sure you will all agree with me that under such conditions our moral and physical well-being as a community would be vastly improved. "There are two great wants," writes Miss Octavia Hill, "in the life of the poor of our large towns, which ought to be realized more than they are—the want of space and the want of beauty."

You may at once stamp these views as Utopian. Speaking for myself, I have every expectation of seeing them realized. I think that if people can only be convinced of a possibility it is not a long step to its becoming a reality. I think I shall have no difficulty in convincing you of the possibility. Although everyone is quite aware that town air is a different article from fresh country air, it excites very little notice unless, as sometimes happens, we are brought face to face with it during foggy weather when the dirt and impurities accumulate under a thick layer of mist. The reason, I think, is to be found in the fact that air is invisible.

"Seeing is believing" is a common saying, and I suppose the reverse is true.

How long has it taken civilized communities to recognize the evil effects of bad water? Clear, sparkling water may contain the germs

of disease, yet we see nothing of them. The death roll of all our battlefields probably does not number so many victims as that of contaminated water. What is the result? An unlimited quantity of pure water is regarded as the first essential to health. We go far afield for it. Manchester, at a cost of £3,000,000, drinks the water from the rivulets of Cumberland. Liverpool pays a high price for the water of the Welsh hills.

As regards the air we breathe, we stand much in the same relation as Mohammed to the mountain. As we can not bring pure air to the town, we go and seek it in the country or by the sea; that is, those of us who can afford it.

But there are many Mohammeds who never see the mountain. How many there are may be judged from this fact, that according to the registrar-general's report, out of a population in England and Wales of 29,001,018 on April 5, 1891, 20,802,770 persons were urban and 8,198,248 were rural, i. e., nearly three-quarters live in towns as against about one-quarter resident in the country.

What is the effect of this town air upon the urban population?

Where changes are occurring which are imperceptibly affecting individuals, and to the cause of which we therefore can not definitely point, it is possible by coordinating a large number of observations to so multiply the effect that we can arrive at a very probable estimate of it and lay our finger on the cause.

By means of *statistics* from the health returns of medical officers we can compare the health of the town with that of the country. Dr. Tatham, medical officer for Manchester, in a life table compiled for Manchester, has shown that "if we take three periods, under 25 years of age to represent youth, the period between 25 and 65 to represent maturity, and ages above 65 to represent old age, it will be found that males in Manchester are young for 94 per cent, mature for 87 per cent, and old for 46 per cent as long as in England and Wales. We are almost forced to the conclusion that in Manchester men grow old sooner than in the country as a whole."

What may be said of Manchester may also be said of Leeds and other industrial towns. This, of course, might be put down to the strain and worry of business life; but if we compare the diseases from which people die in town and in the country, those who have examined the medical returns must have been struck by the number of deaths in towns from diseases of the respiratory organs, pneumonia, phthisis, etc. My friend and colleague, Mr. Wager, of the Yorkshire College, took some trouble to obtain statistics on these points in regard to Leeds, and found that the percentage of deaths from diseases of these organs was considerably greater in the town than in the surrounding districts. As I prepared this lecture, the quarterly return from the medical officer for Manchester arrived for the quarter ending September, 1893, and here I found that out of 400 deaths between the ages of

25 to 45 years by far the largest number (122) are due to phthisis, and the next largest number (38) to pneumonia. This high percentage of deaths from such diseases is characteristic of all large manufacturing centers.

But we need not have recourse to these statistics to assure ourselves of the beneficial effects of fresh air. We have all experienced them. Statistics, however, emphasize the cumulative effect of imperceptible changes—an effect which you will all admit is sufficiently serious.

There is such a thing known as cumulative poisoning. White lead, for example, taken internally in minute quantities will in time produce the effect of a poisonous dose. Bad air is also an example of a cumulative poison.

According to Professor Foster, the average individual inhales 2,600 gallons of air in twenty-four hours, or about 34 pounds by weight, as against 5½ pounds of food, liquid and solid, or six times the weight of food. If we had to buy our air at so much a pound or pay rates on it at so much a cubic foot or gallon, we should take good care that it was not adulterated; for we distinguish fresh air as we do fresh butter from the second-rate article. There is, however, an important distinction between food and air regarded in this way. If the food we take is not quite as nourishing or as good as it should be, the digestive process is sufficiently adaptable to select the good and reject the bad; but the lungs are infinitely more delicate in structure and function, and we can not with impunity inhale a vitiated air and expect our lungs to select the pure and reject the impure without permanent injury to our breathing apparatus as well as to our whole body.

Before passing to the subject of "Town air," I should like you to grasp and keep well before you the idea that we are living at the bottom of a great ocean of air, that we are surrounded on all sides by matter invisible because composed of minute particles (separated by spaces which are big in comparison with the particles) but none the less material.

That the air has weight was first demonstrated by Galileo about the middle of the seventeenth century. I will repeat his experiment:

A glass globe (fig. 1), furnished with a brass stopcock is evacuated by the air pump, the stopcock closed and the vessel then carefully counterpoised. On opening the stopcock air rushes in with a hissing sound, and the balance now sinks at the arm to which the globe is suspended, thus showing that the air has weight.

Now, this invisible matter or gas is not a single gas, but a mixture of gases—mainly two.

One of these gases is nitrogen, an inert gas, whose chief properties are negative. It constitutes about four-fifths of the total bulk of the air and serves to dilute the other constituent, oxygen, which is the active part. This gas helps things to burn and supports life by consuming waste tissue and keeping up the animal heat. In these processes the

free oxygen is removed from the air by entering into combination with the substances which it burns or consumes.

A piece of charcoal is attached to an iron rod, which passes through a metal plate (fig. 2). The charcoal is first heated until it begins to glow, and is then brought into a glass jar containing oxygen. The charcoal immediately glows with dazzling whitness by uniting with the oxygen to form carbonic acid.

I shall have very little more to say about these two gases, but shall now direct your attention to another gas, carbonic acid, which is always present in the air, usually in a minute quantity. Its presence may be most readily shown by exposing to the air some clear limewater in a glass basin, when the surface is soon coated with a white film of carbonate of lime. It is also a very heavy gas, as I can show you by the following experiments:

In fig. 3, *a* represents the vessel containing the clear lime-water, which on standing becomes covered with a white film of carbonate of lime; *b* represents the vessel containing the heavy gas, carbonic acid, upon which the soap bubble floats. The apparatus figured at *c* is for generating carbonic acid. It consists of two vessels, which are connected by glass tubing. The larger vessel contains marble. By pouring acid down the funnel a brisk effervescence occurs, carbonic acid being evolved, which bubbles through the second vessel containing water to remove impurities, and is then used for filling *B* with gas.

A large glass beaker (fig. 4) is suspended at one arm of a balance and carefully counterpoised. By slowly inverting another beaker containing carbonic acid above the open mouth of the suspended one, the latter becomes filled with the heavy gas and descends.

The following table gives the volumes of the different gases in pure air in 100 volumes and also the total weight of these gases:

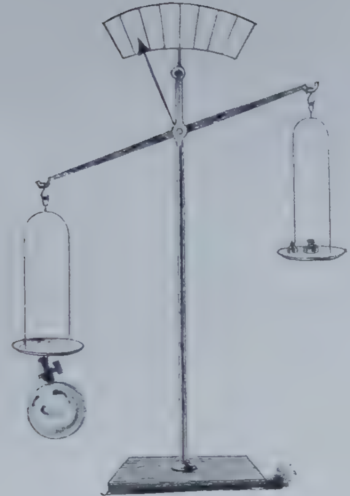
Composition of the atmosphere.

Oxygen	20.61
Nitrogen	77.95
Carbonic acid	0.03
Aqueous vapor	1.40
Nitric acid	Traces.
Ammonia	Traces.
Ozone	Traces.

Composition of the atmosphere in tons.

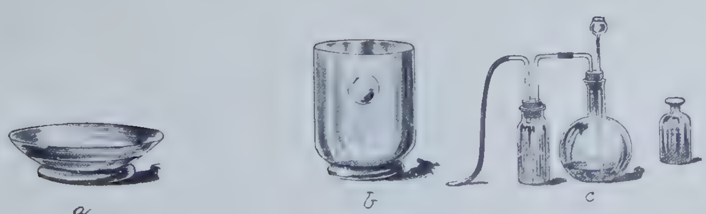
	Millions of tons.
Oxygen	1,233,010,000
Nitrogen	3,994,593,000
Carbonic acid	5,287,000
Aqueous vapor	54,460,000

Where does carbonic acid gas come from? From coal, charcoal, or other fuel when it burns. (The jar in which the charcoal was previously burnt in oxygen was shaken with limewater, and by becoming



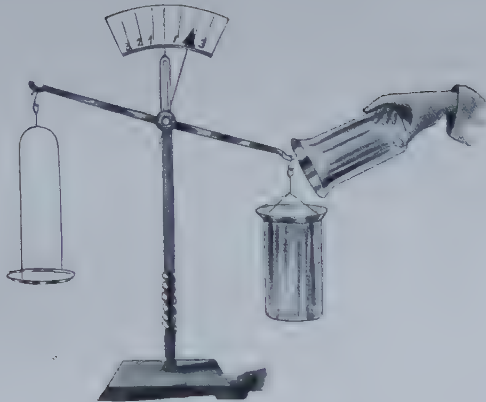
1.—Apparatus for weighing air.

2.—Charcoal in oxygen.

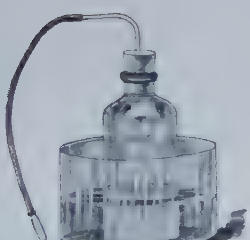


3.—Demonstration of carbonic acid in air.

THE AIR OF TOWNS.

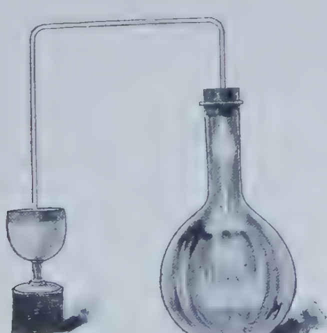


4.—Weight of carbonic acid.



5.—Demonstration of carbonic acid in breath.

6.—Demonstration of carbonic acid in the lungs.



7.—Production of carbonic acid.

THE AIR OF TOWNS.

turbid indicated the presence of carbonic acid.) It is given off from the breath, as the following experiment will show:

By filling a bell jar (fig. 5) with water and breathing air into it from the lungs an atmosphere is obtained within the jar which readily extinguishes a taper, indicating the large percentage (about 5 per cent) of carbonic acid in the breath.

Two bottles (fig. 6), each provided with a double neck, are so connected that air may be drawn into the lungs through the liquid contained in *A* and expelled through the liquid in *B* without removing the tube from the mouth. If clear limewater is introduced into these two vessels, that contained in *B* will very shortly become turbid, indicating the presence of carbonic acid in the lungs, whilst *A* remains clear.

Carbonic acid is produced by fermentation and the decay, which is another form of fermentation, of animal and vegetable substances.

A solution of grape sugar is introduced into a flask (fig. 7), together with a quantity of brewers' yeast. The flask is provided with a cork through which a bent tube passes. The longer limb dips into a test glass containing limewater. If the flask is allowed to stand at the ordinary temperature, the liquid begins to froth and bubbles of carbonic acid rise through the limewater, turning it milky. After a few hours a sufficient quantity of alcohol will be formed to enable its presence to be demonstrated. On bringing some of the liquid into a flask fitted with a long glass tube and boiling it, the vapors passing out of the tube will take fire and burn with the blue flame of burning alcohol.

All these processes go on at the expense of the oxygen of the air, which in time would disappear. It has been estimated that it would require 900,000 years to consume all the oxygen in the air and convert it into carbonic acid. Long before this, however, life would have ceased on the earth, for a slight increase in the amount of carbonic acid or diminution of oxygen would render the atmosphere unfit for respiration.

We are fortunately not threatened by any such catastrophe. No accumulation of carbonic acid can occur in the open air under natural conditions, for although carbonic acid is a heavy gas, it rapidly diffuses.

Two flasks (fig. 8) are connected by a long piece of narrow tube. In the lower flask the heavy gas, carbonic acid, is introduced, and in the upper one, the light gas, hydrogen. Owing to the property of diffusion some of the heavier gas will be found after a time to have passed into the upper flask and the lighter gas to have passed downward.

Carbonic acid therefore becomes quickly disseminated through the atmosphere. Vegetation now steps in. The green coloring matter of plants, termed chlorophyll, has the property in presence of sunlight of splitting up the carbonic acid, absorbed from the air around, into carbon, which it retains for its own growth, and into oxygen, which is restored to the atmosphere. We need not, therefore, trouble ourselves with the

accumulation of carbonic acid wherever vegetation is allowed to flourish, and where the quantity of carbonic acid does not accumulate too rapidly to be dealt with by nature in this manner.

It is therefore obvious that overcrowding, want of open spaces, and the absence of vegetation favor the accumulation of carbonic acid.

Overcrowding has, however, been dealt with by legislation, and where legislation steps in we may be sure that the evil is a real and a pressing one.

Governments and municipalities have recognized the importance of open spaces, of streets of a certain width, of open spaces at the backs of houses, of a certain number of cubic feet for each inmate in lodging houses, hospitals, workhouses, prisons, etc.

This will help to check the accumulation of carbonic acid. But although people are content to live in crowded and smoke-laden towns, vegetation is not so easily persuaded to forego its natural atmosphere, and the smoke question must be dealt with before we can stop the deposition of soot and let in the sunlight to give the necessary vitality to plant life, which should flourish in the very center of our big towns. Let us see now what the evil is. Here is a table showing carbonic acid found in different places:

Carbonic acid in the air.[1]

	Volume, per cent.
In mines, largest amount found in Cornwall	2.5000
Average of 339 analyses	0.7850
In theaters, worst parts as much as	0.3200
In workshops, down to	0.3000
About middens	0.0774
During fogs in Manchester	0.0679
Manchester streets, ordinary weather	0.0403
Where fields begin	0.0369
On the Thames at London	0.0343
In the London parks and open places	0.0301
In the streets	0.0380
On the hills in Scotland, from 1,000 to 4,406 feet high	0.0332
At the bottom of the same hills	0.0341
Hills below 1,000 feet	0.0337
Hills between 1,000 and 2,000 feet	0.0334
Hills between 2,000 and 3,000 feet	0.0332
Hills above 3,000 feet	0.0336

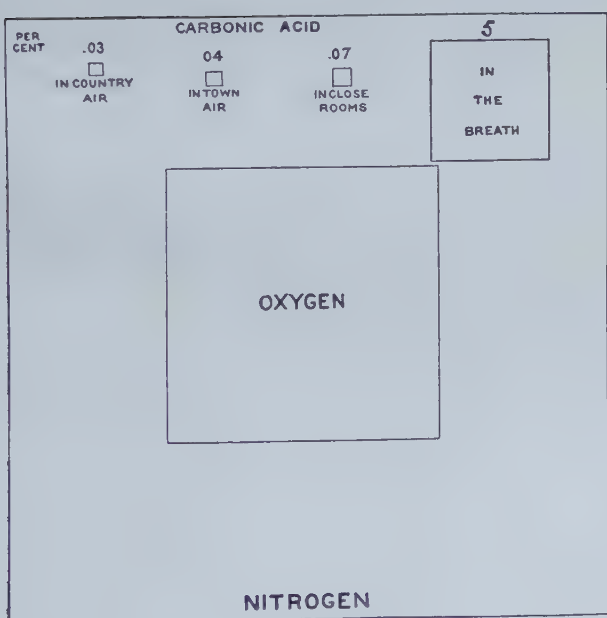
The amount seems very small. Perhaps the following diagram will represent the proportion more graphically:

The diagram (fig. 9) is divided into squares showing the proportion of nitrogen, oxygen, and carbonic acid in the volume of air indicated by the large square.

Although the proportion of carbonic acid in good and bad air is so inconsiderable, we must not be led into supposing that the difference is negligible. There are many examples known to the chemist in which

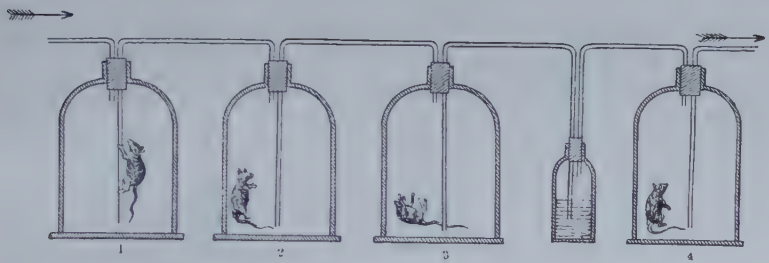
[1] Angus Smith.

8.—Diffusion of carbonic acid.



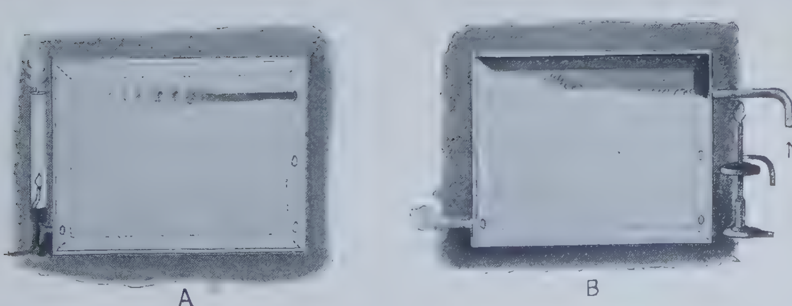
9.—Proportion of gases in atmospheric air and breath.

THE AIR OF TOWNS.



10.—Brown-Séquard experiment with expired air.

11.—Ascent of warm air.



12.—Principles of ventilation and heating.

THE AIR OF TOWNS.

a minute quantity of impurity may produce effects *apparently* quite disproportionate to the cause. We have it on the authority of Professor Roberts-Austen that a difference of one-tenth per cent of carbon in steel rails may be a very serious matter.

The steel cylinder, containing compressed oxygen, which recently burst at the station at Bradford with such fatal effect, contained only three-tenths per cent too much carbon—an amount, however, quite sufficient to account for the mischief.

The steel dies used in the mint should strike 40,000 coins on the average, yet if the die contained one-tenth too much carbon it would not strike 100 pieces without cracking.

Let us see what is the full effect of the difference in carbonic acid in town and country air. If we take country air to contain 0.03 and town air 0.04 per cent of carbonic acid, or a difference of 0.01 per cent, it will amount to about 1 additional quart of carbonic acid inhaled during the day, supposing we take into our lungs 2,600 gallons of air per diem.

This would weigh about 30 grains, an amount sufficient to kill ten people if the poison were as virulent as white arsenic. Moreover, we must remember that if we inhale 1 quart of carbonic acid more we take in 1 quart less of life-supporting oxygen. Is carbonic acid really so poisonous that a quart or gallon more carbonic acid and a corresponding amount of oxygen less would be hurtful to this extent? The answer is "No." Although from experiments made by Angus Smith in an air-tight leaden chamber, when pure carbonic acid was introduced to the extent of 3.84 per cent, two friends suffered after a few minutes from headache, and he himself soon felt great discomfort, it is known that workers in soda-water factories, where the amount of carbonic acid in the air reaches 0.1 per cent, are not injuriously affected. Yet our senses detect the difference between town and country air. We can perceive the difference between Manchester town air and that of the outskirts—a difference of only 0.0034 per cent—or between the air of the streets and the parks of London, which amounts to 0.004 per cent. Why can we detect these minute differences? Because, as Angus Smith says, carbonic acid always comes in bad company. It is its bad companions that affect us. It is the sulphurous acid, which accompanies burning coal and gas; it is the organic poison which accompanies the exhalations from the body.

The latter is the subject to which I now wish to direct your attention.

It is obviously very important to determine minute differences of carbonic acid in the air so that we may guard against the least increase in carbonic acid in the atmosphere. As little as 0.004 per cent can be detected by our senses, as we have seen, and a difference of 0.02 per cent is not pleasant when caused by want of ventilation. Angus Smith says: "We all avoid an atmosphere of 0.1 per cent in a crowded room, and the experience of civilized men is that it is not only odious, but unwholesome. When people speak of good ventilation in dwelling houses they

mean, without knowing it, air with less than 0.07 per cent of carbonic acid. We must not conclude that because the quantity of carbonic acid is small, the effect is small. The conclusion is rather that minute changes in the amount of this acid are indications of occurrences of the highest importance."

What is the substance which accompanies the breath?

Dr. Ransome says that "the aqueous vapor arising from the breath and from the general surface of the body contains a minute proportion of animal refuse matter which has been proved by actual experiment to be a deadly poison. It is this substance which gives the peculiar close, unpleasant smell which is perceived on leaving the fresh air and entering a confined space occupied by human beings and other animals, and air thus charged has been fully proved to be the great cause of scrofulous or tubercular diseases, and it is the home and nourisher of these subtle microscopic forms of life that have lately become so well known under the title of germs of disease or microzymes. It is probably the source of a large part of that increase of mortality that seems inevitably to follow the crowding together of the inhabitants of towns." These views are shared by such eminent men as Dr. Foster, Prof. Du Bois-Raymond, Dr. Carpenter, Sir Douglas Galton, and others.

But in what manner has the above statement been put to the proof?

I desire to refer to a very ingenious experiment which has been carried out by the French physiologist Brown-Séquard.

Fig. 10 represents diagramatically an experiment similar to that of Brown-Séquard. Four bell jars are connected by glass tubes in such a way that by aspirating air through the open tube connected with the fourth bell jar a current of air is made to travel through the series in the direction indicated by the arrows. Between the third and fourth bell jars a vessel is inserted containing strong sulphuric acid, which removes the organic matter from the air passing into the last bell jar. By confining mice in these jars, the first mouse will get the fresh air, the second will breathe air vitiated by the first, and so on, the last mouse breathing the whole of the carbonic acid given off from the lungs of the first three. In this experiment the third mouse would die, but not the fourth, proving that it is the organic poison rather than the carbonic acid in bad air that produces the most serious effects.

Whatever may be the exact nature of this poison, of which little more than its mere existence is known, there can be little doubt that the amount in town air, indicated by 0.001 per cent, produces a cumulative effect upon our vitality, which makes us long for fresh country air, and which no doubt enhances the depression induced by the gloom of our city surroundings.

Health like charity begins at home, and we should therefore start by studying the conditions under which we live in our own dwellings.

Let us consider the case of a person sitting in a room and consuming

2,600 gallons of air in twenty-four hours, or breathing out 16 cubic feet an hour of air containing 5 per cent of carbonic acid. For the air to remain fairly fresh the amount of carbonic acid should not rise above 0.06 per cent; that is to say, the amount of carbonic acid should not increase more than 0.02 per cent, supposing the air to contain originally 0.04 per cent. How much fresh air will be needed per hour? This may be calculated as follows: $\frac{5}{0.02} \times 16 = 4{,}000$ cubic feet.

Air can not be renewed more than three or four times per hour without producing a perceptible current or, as we should say, causing a draft. It therefore follows that each individual should be allotted at least $\frac{4000}{4} = 1000$ cubic feet of air space. This renewal of air in closed places constitutes a branch of study termed *ventilation*. I have not time to discuss fully this important subject. A whole course of lectures might be delivered upon it. All that I can do in the short time at my disposal is to indicate the principles which underly it. The replacement of vitiated air by fresh air without creating draft is the basis of good ventilation.

This necessitates a flow of air. This flow of air may be produced by mechanical means—a fan or pump driving in air, exhausting the bad, or doing both simultaneously—or, more frequently in dwelling houses, by the natural currents produced by hot air.

When air becomes warm it expands. A certain bulk of this air compared with an equal bulk of the original air will be lighter. The warm air therefore ascends, colder air replaces it, and a flow of air is thereby produced.

To show that warm air ascends, a large glass globe open at the top and bottom is supported upon blocks (fig. 11). On introducing a Bunsen burner at the lower opening a strong upward current of air is produced, which causes a spiral of paper pivoted to the horizontal rod to revolve rapidly. Strips of tissue paper gummed around the edge of the top opening form vertical streamers, also indicating the presence of an air current. Toy fire balloons of tissue paper illustrate this property of heated air exceedingly well.

It is for this reason that the warm air, which includes the expired air, finds its way toward the top of a room. It is for this reason also that an open fireplace with a good chimney produces a current of air, which rushes up the chimney to the extent of 150 to 300 cubic feet per minute. These two effects may be combined to draw off the vitiated air by introducing an opening into the chimney near the ceiling. But although by this means bad air is withdrawn and fresh air enters, the method of ventilation can not be considered wholly satisfactory. In my dining room with a good fire burning, I have found that the air passes up the chimney at the rate of 240 cubic feet a minute with the door open, and 200 cubic feet a minute with the door closed. In the first case the fresh air comes mainly through the open door; in the

second, it finds its way through the chinks round the door or between the window sashes. It naturally follows that where cold air is entering through small inlets to supply 200 cubic feet a minute, drafts are frequently experienced by persons in the room, unless mechanical contrivances are arranged for directing the cold air to the top of the room.

It follows that ventilation produced by the currents set up by warm air is closely connected with the methods of warming a room. Regarded from this point of view, the open fireplace is the reverse of economical. The whole of the heating is here produced by radiation; that is, by heat passing from the fireplace to the walls, ceiling, and floor, which in turn transfer their warmth to the air in contact with them, and this represents a small fraction of the heat passing up the chimney.

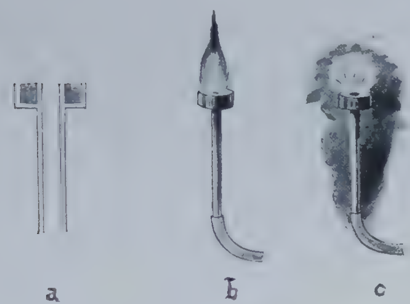
A more economical method is to warm the air of rooms by means of steam or hot-water pipes; but in this case there is no natural ventilation, no fresh air is introduced as with the open fireplace, and special means must be provided to supply the defect.

Another method is to supply a house with fresh air, which has been slightly warmed by passing it around a stove fixed in the basement or out of doors. In this case, if a suitable exit is provided to permit the vitiated air to escape, a constant current of fresh air is set up, which may effect the whole heating and ventilation of an ordinary dwelling house at a comparatively small cost for fuel. In large buildings, such as warehouses and factories, the same result is effected by pumping in at the basement fresh air, warmed by passing through a stove and mixed in any desired proportion with cold air and drawing off the vitiated air by means of an exhaust fan placed at the top of the building. These principles may be demonstrated by the following experiments:

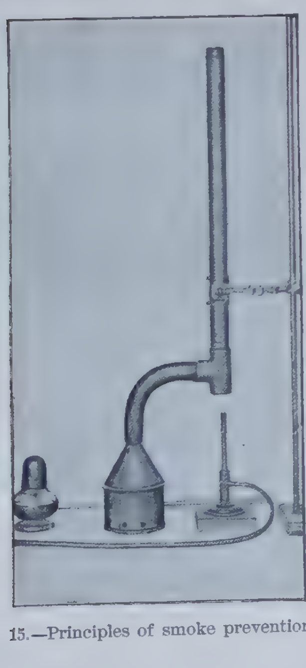
The illustration (fig. 12) represents a shallow, air-tight box with a glass front. Three small circular holes are bored along one side equidistant and one at the bottom of the opposite side. In *A* this hole is fitted with a glass T piece, the top vertical end of which passes through a cork of a lamp chimney. Through the same cork a gas burner is fitted. The box is filled with a dense fog by blowing in ammonium chloride fumes and is brightly illuminated by a lantern. When the gas jet in the chimney is burning, one of the circular holes is opened to the air, and the lower vertical end of the T piece closed, we have on a small scale the conditions of ventilation in a room with an open fireplace. The air enters through one or all of the circular holes, appearing in the fog like black smoke, and the white fumes are observed to issue from the top of the lamp chimney. The other experiment figured at *B* is to illustrate heating and ventilation by warm air. Air enters the box through the bent pipe, which is heated by a burner. The warm air, which appears at the top of the foggy chamber as a dark cloud, gradually displaces the fog, which is driven out at the lower left-hand aperture and the chamber is thus filled with warm fresh air.

The importance of placing within the reach of every person a method of determining quickly and accurately the amount of carbonic acid in the air has induced me to devise a process, a description of which will be found in the appendix.

13.—Luminosity by solid matter.



14.—Experiments with flame.



15.—Principles of smoke prevention.

THE AIR OF TOWNS.

Lecture 2.—Smoke.

Smoke is solid matter given off during burning. Gunpowder smoke is largely mineral salts and so is tobacco smoke. Coal smoke is soot—that is mainly what chemists call carbon. All the common inflammable substances, coal, wood, paraffin, petroleum, benzine, as well as coal gas, contain carbon and in luminous flames the carbon can readily be shown as soot. I have only to bring this white plate into the candle flame and we have as you see at once a deposit of soot. This soot in the flame is white hot and gives to the flame its luminosity. The luminosity imparted by solid matter to a nonluminous flame may be readily demonstrated.

Here is a blow pipe (fig. 13), fed with coal gas and oxygen, which gives as you see a nonluminous flame like burning spirits of wine, but it is nevertheless a very hot one, for as soon as I introduce a lump of infusible material, like quicklime, the latter becomes in a moment white hot and brilliantly luminous.

But an ordinary luminous flame is not necessarily a smoky one, because the soot burns when it reaches the outside of the flame and comes into contact with the air.

Why is it, then, that luminous flames are sometimes smoky and sometimes not? Coal and wood, benzine, paraffin, turpentine, and often tallow and wax candles burn and give off soot. It is because there is too little air where the flame is hottest. The soot as it passes up gets cool and when it reaches a new air supply it is too cold to take fire. It is this that makes a candle, with a wick that requires snuffing, give a smoky flame, because with the long wick it is supplying more combustible to the flame than the surrounding air can burn.

An ordinary oil lamp smokes until the chimney is put on. Then the draft up the chimney is increased, more air is supplied, the flame gets hotter and therefore brighter, and the soot is burned up.

Here is a smoky turpentine flame. By blowing oxygen through the center a brilliant nonsmoky flame is produced.

In *a*, fig. 14, we have a section of the apparatus. It consists of a metal tube, furnished at the top with a hollow metal rim, which is filled with cotton wool soaked in turpentine; *b* represents the smoky turpentine flame and *c* the flame after admission of oxygen.

Soot or coal smoke is then an inflammable part of the fuel and where soot is allowed to escape, the fuel is lost. If, then, we not only feed the flame with more air, but at the same time make the soot hot the smoke is consumed. These are the two simple principles of smoke prevention. Let me show you this by an experiment with a model furnace, flue, and chimney (fig. 15). This consists of a straight metal pipe open at both ends and perforated with air holes near the lower end. A bent metal arm is fixed on by a T piece and represents the flue. The furnace is represented by a turpentine lamp, which burns inside the sheet-iron

case. Volumes of smoke issue from the top of the chimney until a Bunsen flame is introduced within the lower end of the chimney, when the smoke suddenly ceases.

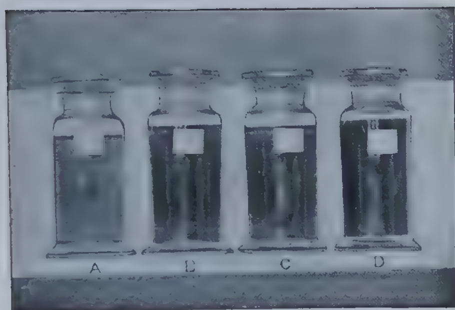
Various forms of grates and furnaces have been proposed for preventing smoke; some utilize more of the heat, and so reduce the consumption of coal; others, by various devices of air inlets at certain times of firing and at special points of the grate, burn up the smoke before it passes to the flue.

I do not intend, for I do not feel competent, to explain the advantages or disadvantages of the large variety of smoke-preventing appliances now before the public. A great deal has been written on the subject by competent persons, and anyone who wishes for information may very easily procure it.[1]

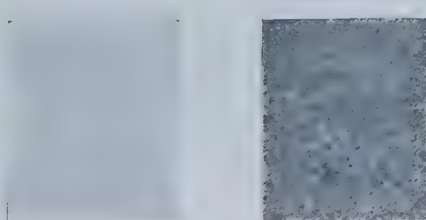
What are the effects of smoke? Before attacking this question, we ought to consider the extent of the evil.

I am making determinations, which are now in progress, and though still very incomplete I am able to give an approximate estimate of the amount of solid matter in the air of Leeds which is mainly due to smoke. There is daily sent into the air of Leeds 20 tons of soot, of which one-half ton falls, and of that one-half ton, 20 to 25 pounds stick; that is, are not removable by rain. How have these figures been arrived at? I have found that in the town 100 cubic feet of air contain on the average over 1 milligram of solid matter which is mainly due to smoke. If, now, we take the most thickly populated area of the city as covering 4 square miles, and supposing the sooty atmosphere to penetrate to a height of 300 feet, the amount of solid matter will be about 800 pounds, constantly floating over these 4 square miles. If, further, we assume that the air of the town is renewed from ten to fifty times in twelve hours, according to the strength of the wind (and it is nearer the latter than the former number, as I will show in a moment), this will mean, taking the higher number, rather under 20 tons of smoke delivered to the atmosphere during the working day. Why do I take fifty as the frequency of atmospheric renewal? The difference in the amount of carbonic acid between country air and town air such as is found on the average in industrial centers like Glasgow and Manchester, and we may also include Leeds, is 0.01 per cent. There are at least 4,000 tons of coal burnt in Leeds every twenty-four hours, yielding 12,000 tons of carbonic acid, and in addition there are 300 tons given off from the lungs of the inhabitants, i. e., in all, 12,300 tons. If we keep to the same area of 4 square miles and the same height of 300

[1] I should recommend the following pamphlets: The report of "The National Association for Testing Smoke-Preventing Appliances," the address of whose secretary is Mr. Fred Scott, 44 John Dalton street, Manchester. "On the abolition of smoke from steam boilers," by T. Patterson, M. D. Publishers, Chronicle Office, Oldham. "The Smoke Nuisance," by Herbert Fletcher, published by John Heywood, Deansgate, Manchester. "Report of the Sheffield Smoke Abatement Association," published by Leader & Sons, 21 Fargate, Sheffield.



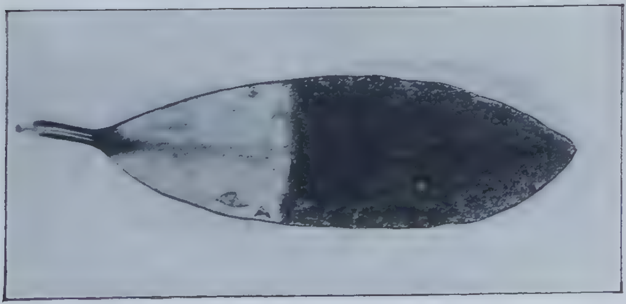
16.—Coal dust in the air.



A. Country Plate. B. Town Plate.

17.—Coal dust in the air.

THE AIR OF TOWNS.



18.—Photographs of leaves, showing deposit of soot; half removed.

THE AIR OF TOWNS.

feet, which we took as the smoke-infected area, the amount of carbonic acid would be about 1 per cent higher in twenty-four hours, or would have to be renewed fifty times in twelve hours to keep down the average amount of carbonic acid to 0.04 per cent.

Let us attack the problem in another way. In Professor Roberts-Austen's report on the London smoke-abatement exhibition a large number of analyses are given, from which it is easy to calculate the weight of smoke from coal burnt in house fires. These analyses refer to different kinds of smoke-preventing domestic fire grates burning different kinds of coal. According to these results about 5 per cent of the coal burnt gets into the air. Mr. Russell, of the Yorkshire College, and myself experimented in the same direction and arrived independently at the same conclusion, without having referred to the results of Roberts-Austen's analyses.

If we take 100,000 tons as the house consumption of coal in the year for Leeds, this is equivalent to about 11 tons in twenty-four hours throughout the year. If we allow an equal amount for factory chimneys, this brings it to 22 tons in twenty-four hours. Or if we follow Scheurer-Kestner and take one-half to three-fourths per cent as the amount of coal given off as smoke from boiler furnaces, then if Leeds consumes 1,500,000 tons of coal a year, or 4,000 tons a day, one-half per cent upon this is equivalent to 20 tons a day. So you see that whichever way we work our calculation we can not get below 20 tons of smoke a day, and I consider that this figure represents a minimum quantity rather than the true average.

And now as to the amount that falls. The winter before last snow fell on January 7. A sample covering 1 square yard was carefully removed from a gravestone in the parish churchyard a short time after the fall ceased. The snow was melted and analyzed. Fresh samples were taken and analyzed on the following three days. They contained a variety of things in solution—ammonium sulphate, sulphate of lime, and free sulphuric acid, all mainly derived from coal. We need not trouble ourselves about these at present, although we can not mask the injury which this corrosive acid produces upon vegetation and the stone and brick work of our buildings.

It is the solid matter which now concerns us.

Here are some of the samples (fig. 16): *A* was collected on the first day, *B* on the second, *C* on the third, and *D* on the fourth. The accumulation of soot is evident from the depth of color.

The weight of solid matter carried down, as determined from the first sample, was equivalent to 16 hundredweight on the square mile. The additional weight of soot which accumulated each day was equivalent to 4 hundredweight on the square mile; or, if we take a smaller quantity as an average over the 4 square miles of the city, we arrive at the daily smoke fall of about one-half ton.

It is impossible to say what proportion of the soot in the air, during the snowfall, the 16 hundredweight represents, but it all points in one

direction, that the waste of fuel in the form of unburnt coal passing into the air is prodigious. Estimated for the whole country, it would mean not an insignificant item of loss to the nation.

Before we can understand the effects of smoke we must learn its composition. I have analyzed two samples, one of which was deposited on the orchid houses at Chelsea during fog, and the other was obtained from my chimney sweep. They contained respectively 14 and 15 per cent of a nasty, sticky oil. Were the soot pure carbon it would be comparatively harmless. It would possess no smell, it would not adhere to anything, and the first fall of rain would wash it away. Unfortunately, this is not the case. Wherever the soot alights a great part of it sticks, and no amount of rain water will remove it. That is why our buildings become permanently black and foliage is discolored.

In order to demonstrate to you the effects of this sticky material in the soot, I analyzed the deposit on three glass plates, 1 foot square, which have been stationed in different spots—one at Pool (about 9 miles from the center of Leeds), one on the roof of the Yorkshire College (about 1 mile from Leeds), and one on the roof of the Philosophical Hall (in the town)—all being removed from the immediate neighborhood of chimneys. This is the appearance (fig. 17) which two plates present after a years' exposure, one in the country and the other in town. *A* remained clean and transparent, whereas *B* was quite opaque.

A series of experiments of this nature extending over many months, in which the deposit after washing was weighed, showed that the deposit on the Philosophical Hall plate was twenty-four times and on the Yorkshire College plate ten times that on the Pool plate, the latter being insignificant in quantity.

The effect of breathing such a filthy atmosphere can only be indirectly gauged. That it plays no insignificant part, by clogging the air passages, in bringing about the high mortality from respiratory diseases, so conspicuous in all industrial towns, can not for a moment be doubted. Its fatal effects upon vegetation are obvious. The green leaf of the plant is its perspiring organ, and the leaf is provided with little pores—the stomata. When these get clogged with soot the plant dies, just as a human being would if the pores of his skin were closed by a layer of varnish. But the soot in the air does more than this. The plant derives the principal material for its growth from the carbonic acid in the air. By the aid of the green coloring matter, the chlorophyll, which is found in the leaf or stem, the carbonic acid of the air is decomposed, the oxygen being restored to the atmosphere and the carbon retained by the plant. This process only occurs vigorously in sunlight. What, then, must be the effect of the black deposit upon the leaf in shutting out that light, and what must be the effect of the smoke-laden air in preventing the passage of the sun's rays?

Here are photographs of two leaves gathered near the town (fig. 18). From half of each the deposit of soot has been wiped off and the

green color then bleached, without disturbing the sooty deposit on the other half.

The diminished amount of sunlight received in the town of Leeds may be gathered from the simultaneous records taken at the Philosophical Hall and at Adel (4 miles from the city). In the year 1892, there was 43 per cent, and in 1893, 30 per cent more sunshine at Adel than in Leeds. This is the record of hours of sunshine, but not of its intensity. The latter, had it been recorded, would probably have shown a still greater difference.[1] I said that the snow in the parish churchyard contained acid—sulphuric acid. This acid is, like soot, derived from coal, for it is never found in the country. The sulphur in the coal, which is present to the extent of from 1 to 3 per cent, burns, and a portion passes up the chimney as sulphurous acid, and then into the open air. It is this sulphurous acid which imparts to town fog its choky and irritating effects. In the open air it is rapidly converted into the much more corrosive substance—sulphuric acid, which nearly always accompanies soot, and it is found with soot on leaves, and probably promotes their early withering near towns. Moreover, it corrodes the mortar and stone work of our buildings.

The following table, prepared by the Manchester air analysis committee, gives the analyses of deposits upon leaves gathered in and near the city. The places are arranged in the order as we pass from the outskirts to the center of the town:

Deposits on holly or aucuba leaves collected December 14–16, 1891.

[Milligrams per square meter of leaf surface.]

Locality.	Solid matter.	Sulphuric acid.
Alexandra Park	131	7.2
Owens College	315	10.4
Hulme	420	26.0
Harpurhey	443	19.0
Infirmary	728	27.5
Albert Square	833	24.2

It has been said that however much you may do away with smoke, you will never remove this acid; it will still pass into the air. Quite true; but to anyone who advances that as an excuse for the smoke maker, I would say this: Soot is an oily substance not wetted by water. The acid, therefore, attached to it is not washed away by rain so rapidly as it certainly would be, if it were not in contact with this film of oily matter. Although sulphurous and sulphuric acids are injurious to plants, I do not believe the quantity given off from our chimneys would prove nearly so hurtful as it is now in company with soot.

There are real or imaginary difficulties in the way of stopping smoke from house fires, yet I firmly believe that before another generation has

[1] Since this lecture was delivered experiments on the intensity of the light have been made and will be found in Appendix II.

passed away people will look back upon the hideous heap of black stones stowed away in an ornamental box in every dwelling room as we now contemplate the tinder box or the tallow candle. But if domestic chimneys are responsible for half, or even more than half the smoke, it is no reason why we should suffer from the other half if it can be removed. Let me now direct your attention to the legal aspect of the question. It may be said that this lies beyond the province of the scientific man, but my conscience would not be satisfied if I did not link to a subject, which I regard as of serious importance, the knowledge of how the evil may be compassed. Legislation in regard to smoke abatement is to my mind as simple as it is just.

The Public Health Act, 1875, part 1, subsection 7, states:

"For the purposes of this act, any fireplace or furnace which does not, as far as practicable, consume the smoke arising from the combustible used therein, and which is used for working engines by steam, or in any mill, factory, dyehouse, brewery, bakehouse, or gas work, or in any manufacturing or trade process whatever, shall be deemed to be a nuisance, and liable to be dealt with summarily in the manner provided by this act."

This is in regard to furnaces. In respect of chimneys, the second part of subsection 7 of section 91 says:

"For the purposes of this act any chimney, not being the chimney of a private dwelling house, which emits black smoke in such quantities as to be a nuisance, shall be deemed a nuisance, and liable," etc.

Put briefly, the law is this: Every factory-chimney owner who is not using the best practicable means for preventing smoke, whether the quantity is large or small, is acting contrary to the law.

Before the alkali act existed, wherever alkali makers erected their plant they were like plague spots; vegetation died for miles around, making the neighborhood of the works a bare wilderness like the district of St. Helens is to this day. The alkali act did not stop these works. It simply prescribed that the best practicable means should be adopted to prevent the escape of acid, and inspectors were appointed to see how far this could be carried out. What happened? Before long a most efficient method was found to condense the acid fumes. The acid turned out to be a profitable commercial article, and now the amount of acid escaping into the air is invariably under the minimum quantity—a very minute amount—prescribed by the present act of Parliament.

Government has acted with equal wisdom in regard to factory chimneys. No particular form of furnace is prescribed, but only the best practicable means for preventing smoke.

If, then, a manufacturer is sending out not black smoke, but one particle of soot—

"Be it so much
As makes it light or heavy in the substance
As the division of the twentieth part
Of one poor scruple; nay, if the scale do turn
But in the estimation of a hair,"

19.—Leeds, England; overlooking Kirkstall Road. (From photograph.)

THE AIR OF TOWNS.

which might by other and better means be prevented, he violates the law.

The second part of the act relating to chimneys should be unnecessary if the first were properly carried out. That it is necessary, arises from the fact that convictions are almost impossible, because the smoke maker may always urge in his defense that his furnace is the best he can procure for the purpose, which statement the magistrate is usually willing to accept.

Could it be shown that the complete consumption of smoke would be to the advantage of the smoke maker, as it was in the case of the alkali maker, factory chimneys would soon cease to smoke. Before I go further, I wish to establish a claim to understand the smoke maker and to sympathize to some extent with him. I was for a few years assistant manager in a large chemical works. If there is an industry where excuse may be found for smoke it is in a chemical works. Of the five boilers on the works some were used for machinery, others for distilling purposes. Sometimes during the day the boilers were working at low pressure, at other times they had to deliver the maximum amount of steam. Then there were a large number of small furnaces for special products, and here, again, the firing was irregular from the necessity of the case. In addition to this, noxious vapor had to be treated before the gases escaped into the chimney. One could scarcely expect that with all this intermittent firing, the chimney should make no smoke. Much more might be urged on the part of smelting works, which have even greater difficulties to encounter in the way of fume and the nonobstruction of draft. Yet no works are exempt from the act, and the best practicable means should be enforced everywhere.

Now, although I think I am able to take a fair view of the manufacturer's case, my sympathies, I confess, are with the workingman. No doubt some of these men, the firemen, are directly responsible for much unnecessary smoke. This has often been advanced as an excuse for the manufacturer. I do not think it is a legitimate one. A manufacturer ought to know and appreciate better than his workmen the evils of smoke, and should exercise the authority he possesses to enforce his more enlightened ideas. It is certainly the workman who bears the brunt of the polluted atmosphere. I lived for a time near the works I have described, right in the heart of a manufacturing district. Of the character of the district you may form some idea from the fact that within almost a stone's throw of my door were three tar works, two other chemical works, an iron foundry, a fire-brick works, a colliery, and an alkali works. Opposite my lodging was a row of cottages similar to the row in which I lived and behind it, like a great scaffold, rose the winding gear of the colliery. At the back of the house was the yard of a tar works with its desolate, black beds of pitch, and beyond a mountain of alkali waste, sending forth day and night its fetid odor of sulphuretted hydrogen. This smell, combined with the

vapors of pitch, which was run out in the early morning, was sometimes wafted into my bedroom and would awaken me with an indescribable feeling of nausea. Fill up the scene with a forest of smoky chimneys, begrimed walls, screeching steam whistles, and the steady rumble of strings of coal carts, and you have a picture which represents the not unusual surroundings of the workingman in a manufacturing district. There he lives, buried in one great, blank mass of ugliness, neither vestige of green around his dwelling nor even an untainted sky above his head.

I do not think that in passing through such a spot it is possible to imagine the life that belongs to these surroundings. It certainly made an impression upon me, which I never previously realized and which I shall not readily forget. Perhaps not the least melancholy side to this picture is the reference, which Mr. Acland made to it in a recent speech: "All those who are making a careful study of the condition of our towns were perfectly aware of this fact, that a great deal of the work in the towns, which necessitated strong and healthy men, especially in London, was done by those who had been brought up in country homes, and not in those of the towns." However, I have no wish to appeal to any sentimental feeling. Political economy has nothing in common with it, we are told, and "business is business," which I suppose means the same thing. I have pointed out that some few works have to fire their furnaces intermittently and some smoke or fume may be unavoidable. This does not apply to the large majority of steam users, who require a fairly steady steam pressure throughout the day. Let us see what is the opinion of persons who have carefully studied the question.

The Sheffield Smoke Abatement Association subcommittee, after a careful experimental inquiry, state that "it is certain that smoke may be almost entirely and completely prevented from steam-boiler chimneys." Deputations from the corporation of Bolton, Rochdale, Blackburn, Bury, Oldham, Middleton, and many local boards, made a round of visits to smokeless works, and the corporation of Rochdale passed a resolution that there was to be found in the market apparatus, by which coal could be burnt for trade purposes economically and smokelessly. A special subcommittee of the Blackburn corporation passed a resolution, stating that "they are convinced that the smoke nuisance in Blackburn can be for all practical purposes done away with by the application of these coking machines, and that it is of advantage to the steam users to use them; and they are further of opinion that no hardship will be inflicted upon steam users if the law respecting nuisance from smoke is strictly enforced." The larger boroughs named are now all prosecuting.

From the following list of works using smokeless appliances, compiled by Mr. Herbert Fletcher in 1888, it is interesting to note the great variety of industries represented. To this list must be added, further, 28 firms representing 174 boilers since adapted with smokeless appliances.

INSTANCES OF FIRMS USING SMOKELESS FURNACES.

The following is a list of firms who are known to be burning bituminous coal smokelessly, and whose works should be visited by manufacturers before stating on oath that they have done everything possible in order to comply with the Public Health Act. The furnaces are by Vicars, Sinclair, Cass, and Jukes:

Royal Mint	London.
Hydraulic Power Co	Do.
Lion Brewery Co., Lambeth	Do.
Southwark and Vauxhall Water Co	Do.
De la Rue & Co., printers	Do.
Waterlow & Son, printers	Do.
Sir Jos. Causton & Sons, printers	Do.
Wm. Clowes & Son, printers	Do.
Wyman & Sons, printers	Do.
Jos. Barber & Co., wharfingers	Do.
J. S. Bradford, paper makers' materials	Do.
Leadenhall Market Cold Storage Co., ice makers	Do.
J. W. French & Co., flour mills	Do.
Vogan & Co., millers	Do.
W. B. Dick & Co., oil mills	Do.
Jas. Gibbs & Co., oil mills	Do.
Peak, Frean & Co., biscuit makers	Do.
Henry Tate & Sons, sugar refiners	Do.
David Martineau & Son, sugar refiners	Do.
Abram Lyle & Son, sugar refiners	Do.
D. & W. Gibbs, soap works	Do.
Rich'd Wheen & Son, soap works	Do.
Jno. Knight & Son, soap works	Do.
Hy. Ashwell	Nottingham.
Tetley & Son, brewers	Leeds.
Tait & Sons, sugar refiners	Liverpool.
Gossage & Sons, soap works	Widnes.
Musgrave & Sons, cotton spinners	Bolton.
Walter Cannon, cotton spinner	Do.
P. Crook, Limited, cotton spinner	Do.
Wardle & Brown, cotton weaving	Do.
John Fletcher, colliery	Do.
Astley & Tyldesley Coal Co., colliery	Manchester.
Colman, mustard	Norwich.
Electric Supply Co., electricity	Liverpool.
Brandley Mining Co., Limited, lead mines	Keswick.
Wilson, "Evening News"	Edinburgh.
North British Rubber Co., india rubber	Do.
R. & R. Clark	Do.
Alex. Cowan & Son, paper	Do.
Jas. Milne & Son	Do.
W. & R. Chambers, printers	Do.
Gall & Inglis, printers	Do.
Gunn & Cameron, "Daily Mail"	Glasgow.
Brown, Stewart & Co., paper mills	Do.
J. & P. Coats, thread mills	Paisley.
F. S. Sandeman, jute mills	Dundee.
Pirie & Sons, paper	Do.
Robertson & Orchar, iron foundry	Do.
Chas. Lyell	Do.

There is only one conclusion to be drawn from this, that the majority of smoke makers are acting in violation of the law. The smoke banners which they fly from their chimney tops are the black flags of piracy. They are pirating the pure air, which is the property of everyone.

Here is a scene (fig. 19) which may be observed any hour of the day in Leeds.

What remedy, then, should I propose? I would have a government,

not a municipal, smoke inspector, a scientific man of wide practical experience, like our alkali inspectors—the offices in fact might be combined. In the matter of smoke abatement, the local authority and inspector are useless. I am not speaking specially of Leeds, for in nearly every town where a strong desire has been shown to abate smoke, the local authority, which had the power, has usually done nothing. The ratepayers' representatives are either smoke makers or have smokemaking friends, and the municipal smoke inspector is, as a rule, not equal to the task.

The relation of a municipal to a government smoke inspector might be compared to that of a sympathetic friend and the family doctor. You have a bad headache and feel ill and your good-hearted friend calls in. After making inquiries, he suggests various remedies as certain cures for your ailment. You say you have tried everything under the sun, but you are no better. Then comes the family doctor. "Hello!" says he; "I see what is wrong; we'll soon put you all right."

I will read you the deliberate utterance on this subject of Her Majesty's ex-chief alkali inspector, Mr. A. E. Fletcher, which ought to carry weight:

> "There are difficulties in making any change. Masters will not take the trouble to alter their furnaces, nor will the men alter their method of stoking the fires unless they are compelled. The numberless alterations made in the construction and conduct of chemical works during the last twenty years would never have been carried out but for the pressure brought on the manufacturers by means of the alkali act. So it will be with the smoke nuisance. Men are too idle or too much occupied to move in such a matter until pressure from outside is applied. The moral pressure must come from the public, and it should be made some one's business to see that the law regarding it is put in force."

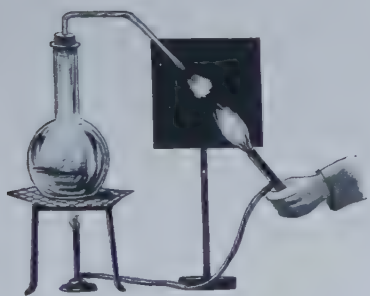
This question is a workingman's question. He is or should be most interested in it. His health, his home, and his surroundings are infected by the smoke plague far more than those of his wealthier neighbors.

I believe that if the employer were obliged to put in an efficient smoke-preventing appliance, of which there are several in the market, he would reap advantages in two ways. He would probably economize in fuel and the health of his workmen would be improved. But, as the alkali inspector says, the manufacturer will not change his method until he is obliged, and the moral pressure must come from the public.

May it before long be said of Leeds not only of the morning, but of all and every day,

> "This city now doth like a garment wear
> The beauty of the morning; silent, bare
> Ships, towers, domes, theaters, and temples lie
> Open unto the fields and to the sky
> All bright and glittering in the smokeless air."

20.—Moisture drawn from the air.



21.—Moisture taken up by the air.

22.—Dust particles in the air (highly magnified).

THE AIR OF TOWNS.

LECTURE 3.—TOWN FOG.

Before discussing the nature and effects of town fog, we will begin, as in the first lecture in the case of carbonic acid, by seeking for its origin.

Town fog is mist made white by Nature and painted any tint from yellow to black by her children; born of the air of particles of pure and transparent water, it is contaminated by man with every imaginable abomination. That is town fog. How does this mist arise? It is water vapor or steam always present in the air in varying quantities, which by a fall of temperature suddenly appears either as mist or rain, snow, hail, or dew, according to the extent and rapidity of cooling and the amount of water vapor present in the air at the time. The following experiments will make this evident:

A little ether is placed in this bright silvered cup (fig. 20); on rapidly evaporating the ether by blowing air through it by means of a hand bellows the temperature is lowered, and the bright surface soon becomes dimmed with a deposit of moisture from the air.

If, on the other hand, I bring a flame under the jet of steam (fig. 21), which is now visible through partial condensation in the form of mist, i. e., fine water drops, the mist suddenly vanishes, for the warmer air can now take up the water in its invisible form as vapor. When I remove the flame the mist again appears.

There is one interesting and curious fact about the formation of fine particles of mist or the larger particles we call rain drops or dew—that the starting point, the nucleus, of each of these particles of water is a speck of dust, a speck so minute that it is generally invisible to the naked eye. Without dust there is no mist or rain or dew. It is solid matter which is the starting point for the deposition of moisture. What would happen if air free from dust were saturated with moisture and the temperature fell? Water would be deposited, but only on solid objects. It would deposit on the ground and on our buildings. It would stream down the walls of our houses and soak the surface of the earth. Every solid thing out of doors would be wet, but no mist would appear and no rain would fall.

Mist is the offspring of vapor and dust. What is the character and quantity of this dust? We know that it exists. We know that it is very plentiful in our houses. As far as we know, it exists everywhere; but of course the quantity varies and varies enormously, as we shall presently see.

Here is a slide (fig. 22) which shows some of the things composing the dust of a dwelling room highly magnified.

We find in it particles of soot, crystals, fibers, vegetable cells, spores and pollen grains, starch grains and meteoric iron, the remains of insect life, and living germs. Of the character of this dust, I shall have more to say in my next lecture. Much of it is so fine that it is invisible under

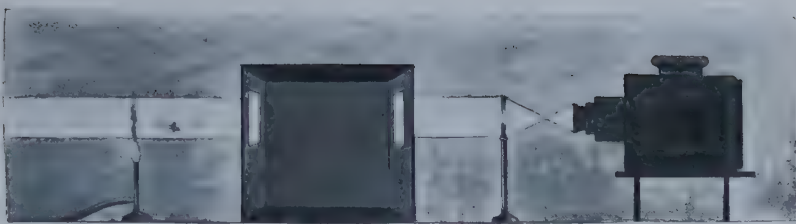
ordinary circumstances. It is only when a beam of light in a darkened place, a ray of sunlight in a room, a street lamp on a dark night, illuminate these little particles so that they stand out against a darker background that we see them—the so-called motes dancing in the beam. It is, in fact, these little particles which make the beam of light. Without the particles the path of the beam would be invisible. The path of light from a luminous body without solid matter to obstruct and reflect it is absolute and unqualified darkness. Here, if I pass a strong beam of light from an electric arc lamp (fig. 23) through the side windows in this wooden box free from dust the beam is cut out where it enters the box and reappears on the other side, where the light emerges.

We can learn something more from this experiment. The dust is mainly organic; that is, the product, living or dead, of animal and plant life, living germs or dead spores or animal and vegetable refuse matter; for if I now bring a red-hot poker or a Bunsen flame beneath the beam, black smoke appears to rise. The black smoke merely indicates the absence of dust particles where they are burnt up by contact with the source of heat. I will now perform a third instructive experiment to show how little of the dust breathed into our lungs finds its way back into the air; for the air passing out of the lungs cuts a hole in the beam, showing the absence of dust in the breath. These interesting experiments were first devised by the late Professor Tyndall.

I take an ordinary lamp chimney (fig. 24), at the bottom of which a bent tube passes through a cork. By breathing out air from the lungs at the constricted part of the beam, the beam is interrupted from the absence of dust.

And now let us see how far our theory of fog is capable of illustration.

I have in this large glass vessel (fig. 25) air standing over water. The air is of course saturated with moisture. There is within the vessel a little electric lamp, which will render more evident any change taking place within. If I cool the air, moisture will be deposited, but according to our theory it should only appear as mist, if dust particles are present. As the air in the vessel has been standing out of contact with the outside atmosphere for two days, we may assume that the dust now has all subsided and dropped into the water. On cooling the air, we should see no mist. We can cool the air conveniently and rapidly by making use of the property which air possesses of becoming colder on sudden expansion. I have only then to exhaust the air partially by an air pump by attaching it to this bent tube which passes into the interior to produce the necessary conditions for the formation of mist. Now I have done so, and you observe that no mist appears. I can now, through this second bent tube, draw in a little air laden with dust from the room. I will now cool the air again, and you see at once that a fog appears within the vessel. If I pass in more dust particles, which I am now doing, and pump out the air again, we have



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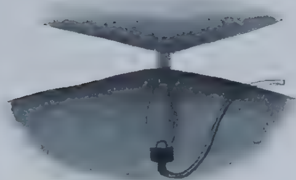

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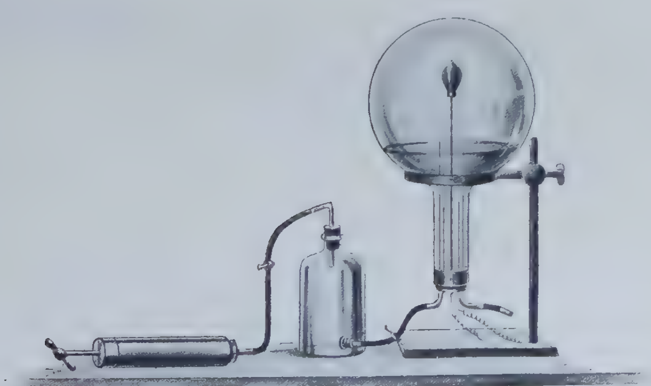
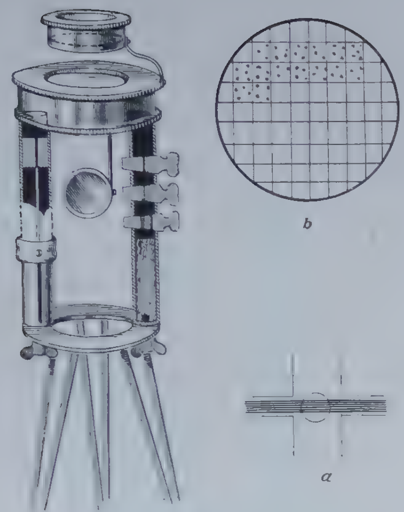
23, 24.—Beams of light through dustless air.



25.—Nature of fog.

THE AIR OF TOWNS.



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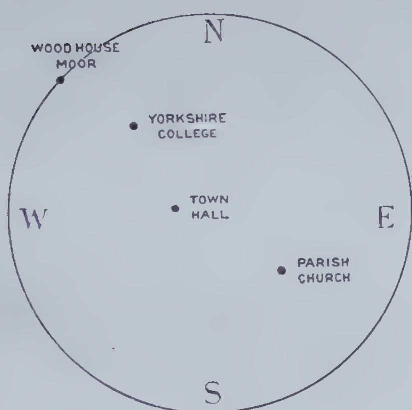

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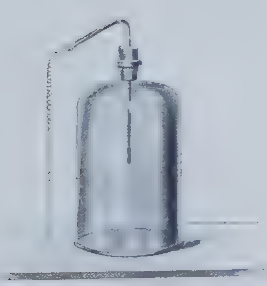
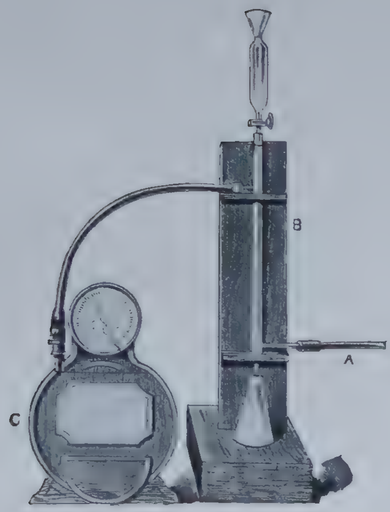
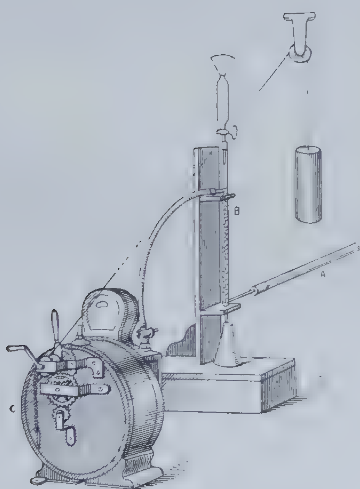


28.

THE AIR OF TOWNS.—DETERMINATION OF DUST PARTICLES IN THE AIR.





29

THE AIR OF TOWNS.—DETERMINATION OF SULPHUROUS ACID IN THE AIR.

a very typical and dense Leeds fog. The more dust particles there are, the thicker the fog.

Before passing to the subject of town fog, I should like to say a word or two about the weight and number of those dust particles which we see play such an important part in the production of fog. The experiments we have just seen have been turned to account by the distinguished physicist John Aitken, to determine the number of dust particles in the air. By using a small vessel and dusty air largely diluted with air free from dust, he has succeeded in producing an apparatus, in which the dew drops or mist drops are sufficiently small in number to be counted. As the apparatus is exceedingly simple in construction, I propose to explain it. Fig. 26 represents the instrument, which for the sake of explanation, is drawn partly in section. It consists of a shallow circular metal box of known capacity, furnished top and bottom with glass plates. It stands upon two cylinders opening into it. One cylinder forms a small air pump and contains a piston. The other is provided with three taps, the bores of which hold a measured volume. The top tap holds the smallest and the bottom one the largest volume. Below these there is a plug of cotton wool, and at the bottom of cylinder, which is closed at the end, is a small hole through which air can enter. Above the metal box is a magnifying lens and below a reflector. The lower glass plate of the box is divided into measured squares, etched on the glass. The atmosphere within the box is kept saturated with moisture by means of strips of damp blotting paper. By drawing down the piston with the taps in the position shown in the diagram, air enters the metal box through the cotton plug, which frees it from dust. To test a sample of air, one of the taps (determined by the amount of dust present) is turned through a right angle so that the bore is horizontal. It now communicates directly with the outside air as represented at *a*, which shows it in section. By turning it back, the bore again communicates with the metal box. The piston, which is at the top, is now drawn down and the sample of dusty air is drawn up along with filtered air into the metal box. By again raising the piston and drawing it down rapidly, a deposition of moisture occurs, which falls in drops on the glass squares, such as is represented on the top squares in the diagram at *b*. These drops are counted and from this the number of dust particles may be ascertained.

The following are the average number of dust particles in town and country air taken from Aitken's observations: Country, 8,000 to 100,000 per cubic inch; town, 1,000,000 to 50,000,000 per cubic inch. I was not satisfied with simply exhibiting Mr. Aitken's results, and so I borrowed the instrument, which he kindly placed at my service, in order to find out the character of the air in Leeds. The following results were obtained on a fine day with the wind blowing from the northwest. The relative position of the places of observation are noted on the diagram (fig. 27).

Number of dust particles in Leeds air.

	Per cubic inch.
Woodhouse Moor, northwest wind	530,000
Tennis Court, Yorkshire College	852,000
Town Hall Square, Leeds	1,228,000
Paris Churchyard, Leeds	3,638,000
Glasgow Town, northwest wind (Aitken)	3,736,000
Flour mill, Leeds	3,113,000

There is one curious fact about these results, to which I would call your attention. There are, you will observe, fewer dust particles in a flour mill, where the air is thick with dust, than in the comparatively clear air of the churchyard. This was a puzzle to me at first, but I think it may be explained by the fact that the particles in the flour mill are larger and therefore more visible. As to the size of the particles, they may be accounted for possibly by coalescence produced by electrification. This curious effect of coalescence of dust particles by electrification may be easily demonstrated. We have only to connect one conductor of an electric machine with a wire passing through the top of a bell jar containing fumes from burning magnesium, when, on turning the machine, a little whirlwind of particles is set up and in a moment, as you see, all the solid matter has deposited in coarse grains round the sides of the vessel (fig. 28).

Let us now return from this digression to the fog once more and follow its life history.

With a calm atmosphere, a high barometer and a fall of temperature, a film of water coats every little floating particle of dust, as it were, with an overcoat to keep out the cold. A white fog slowly enshrouds the town. Each particle of dust now heavily weighted with its unwonted cloak of moisture has its progress impeded, hangs or falls, but does not rise, and in its turn impedes the movement of the air. Stagnation of the atmosphere is produced, especially as wind is light with fog. What happens? An accumulation of products of combustion occurs, viz, of carbonic acid, sulphurous acid, and soot, which under ordinary conditions are rapidly dispersed. Our senses give us abundant evidence of this in the case of soot and sulphurous acid. Our faces and clothes are soon begrimed and our eyes and throats suffer from the irritating effects of the acid. Carbonic acid shows a like increase, again illustrating the well-known axiom that carbonic acid always comes in bad company.

The table which I now project on the screen shows the increase of carbonic acid during fog:

Carbonic acid in London air.[1]

January 19, 1882. Slight white fog	0.048
January 25, 1882. Dense black fog	.105
February 1, 1882. Very fine	.047
February 3, 1882. Slight fog	.062
February 4, 1882. Dense black fog	.107

[1] Dr. Russell.

February 14, 1882. Very fine	0.041
December 8, 1882. Fine	.040
December 10, 1882. Thick, white fog	.094
December 11, 1882. Thick, white, darker	.110
December 11, 1882. Later very dark	.141
March 31, 1883. Fine	.037
April 3, 1883. Very foggy	.133

You will notice that where the fog is long continued the amount of this gas increases threefold.

The next slide gives the average amount of sulphurous acid in Manchester air during four months of 1892, as determined by the Manchester Air Analysis Committee:

Sulphurous acid in Manchester air.

[Milligrams of SO_3 per 100 cubic feet.]

Month.	Minimum.	Maximum.	Average.
September	0.7	3.5	1–2
October	0.7	6.0	2–4
November	2.0	12.0	6–8
December	3.0	30.0	6–10

And the following table gives a number of determinations from the same source in the outskirts and the center of the town, showing plainly the increase of acid during fog and the larger proportion in the center of the town:

[Milligrams of SO_3 in 100 cubic feet.]

Date.	Outskirts.	Center of town.
September 5	0.7	1.8
October 14	0.8	3.53
November 5	1.7	4.9
November 10	2.5	4.1
November 13	3.3	7.6
November 17	2.0	5.9
November 19	2.96	8.4
November 22	4.2	*a* 9.7
November 27	9.3	*a* 15.7
December 17	2.3	9.2
December 21	16.5	*a* 32.2
December 22	12.7	*a* 22.6
December 23	12.7	*a* 25.8

a Fog.

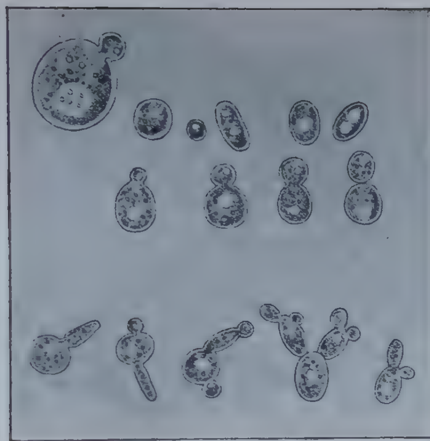
I should now like to explain to you briefly the apparatus which I devised for the Manchester Air Analysis Committee for making these determinations of sulphurous acid.

The apparatus used for the determination of sulphurous acid in the air consists of three parts (fig. 29). A, a long glass tube, about half an inch in diameter, open at both ends, which is fixed horizontally so

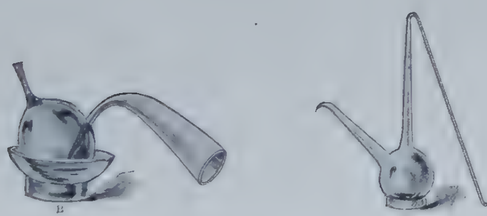
as to project into the open air; B, a glass tower, about 30 inches high and $1\frac{1}{4}$ inches in diameter, open at the top, and drawn out into a fine jet at the bottom. Two side tubes are fixed to the tower, one near the bottom and the other on the opposite side near the top. The tower is filled to within 1 inch of the upper sidepiece with glass beads, and into the open top a tap funnel is inserted through a tightly fitting cork. The lower side tube is attached to the horizontal tube; the upper one, by means of wide india-rubber tubing, to a combined meter and aspirator, C. This is an ordinary wet meter converted into an aspirator by attaching toothed wheels to the revolving drum and driving the wheels by means of a wire cord passing over a pulley and carrying a weight. A series of dials register the volume to the one-hundredth of a cubic foot. The method of conducting the experiment is as follows: About 250 cubic centimeters of a solution of hydrogen peroxide in water, containing about 1 milligram of active oxygen in each cubic centimeter, is poured into the tap funnel, from which it is allowed to drop onto the glass beads at the rate of about one drop a second. The liquid passes down and out at the lower end of the tube through the jet, and falls into a flask placed below. A drop of liquid which permanently fills the jet seals it effectually from the entrance of air from the interior of the room. After running through, the liquid is poured back into the funnel. The weight being wound up, the volume indicated on the dial is read off, and the drum set in motion. With a column of beads of about 20 inches and a weight of 20 pounds, 20 cubic feet can be aspirated in an hour. Once started, the apparatus needs no further supervision until either the weight has reached the ground or the solution of hydrogen peroxide has run out of the funnel. The period required for this is readily determined, so that no time is lost in looking after the apparatus.

Thus we see that carbonic acid and sulphurous acid, as we should have anticipated, rapidly increase during fog, and, although I have no determinations of soot to record, the fact that it increases also is sufficiently evident.

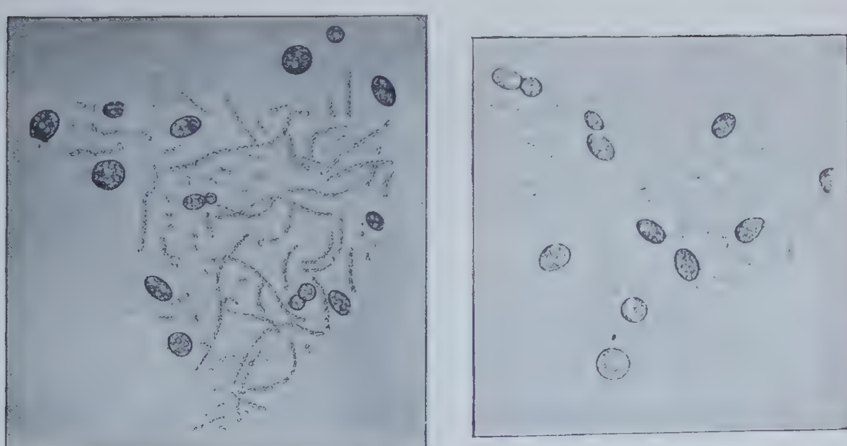
If we assume that dust particles are the cause of fog, then it follows that the thickness of fog depends upon the number of these particles and the fog must be denser in the town than in the country. Moreover, each particle of water floating as fog becomes coated with a film of sooty oil—of that oil which forms so large a constituent of soot. What is the effect? Evaporation is retarded and the fog persists longer than it would were these particles composed of pure water only. To illustrate this, I wish now to refer to an experiment, which has been proceeding since the beginning of the lecture. I then called your attention to the fact that in each pan of this balance I had placed a large watch glass containing water. Onto the surface of one watch glass of water I had poured a drop of oil, which spread itself out into a film. You now observe that this pan has descended, showing that evaporation has proceeded at a greater rate in the other pan.



30.—Yeast plant.



31.—Cause of vinous fermentation.



32.—Acetic and lactic ferments in sour beer. (Pasteur.)

THE AIR OF TOWNS.

We have not yet touched upon the evils attending fog. Apart from the cost due to the extra daily consumption of gas, which is estimated in London at 25,000,000 cubic feet, or £3,125 per annum, there is a serious increase in mortality. The figures in the following table must be taken with some caution, as it is recognized that a fall of temperature increases the death rate; but there can be little doubt that the high mortality due to respiratory diseases which occur with the advent of fog must be in a large measure directly traceable to this cause:

Sickness and mortality in Manchester during the months of December (1890), January, and February (1891).

[Estimated population, 506,325.]

Week ending—	Weather (Town Hall).	Thermometer.		Sickness (weekly numbers).		Deaths (weekly n'mb'rs).	
		Maximum.	Minimum.	General, treated at public expense.	Infectious, reported to medical officer.	All causes.	Respiratory diseases and phthisis.
Dec. 6	Dry and cold, thawing	48.6	29.8	780	70	244	85
Dec. 13	Dry east winds, hard frost, some fog.	40.1	25.8	719	83	238	87
Dec. 20	do	40.1	18.6	672	70	294	121
Dec. 27	Dry east winds, hard frost (dense fog three days)	40.8	15.8	448	56	393	204
Jan. 3	Overcast, severe frost	41.8	26	691	59	328	165
Jan. 10	Overcast (foggy two days)	40.8	21.7	801	52	341	153
Jan. 17	do	43.8	27.8	853	66	336	156
Jan. 24	Overcast	48.7	17	708	51	278	109
Jan. 31	Overcast (clear two days)	51.6	36	818	61	263	95
Feb. 7	do	51.4	34.7	802	52	211	78
Feb. 14	Overcast	50.1	37.2	866	62	232	91
Feb. 21	Dull (dense fog two days)	52.7	27.6	787	54	291	104
Feb. 28	Clear (dense fog one day)	56.7	29	929	62	257	113

I have little more to add. We have learned one important lesson, viz, that dust is the mother of mist and rain.

Looking at the statistics of the annual rainfall since the beginning of the century, there appears to be a slight increase; but it may not be due to an increase of solid matter in the air. Whatever the facts may be, it is interesting to remember that dust is its own destroyer. Rain, snow, and mist drag it to the earth, and so wash and purify the air. Were it not so, though the ground would still receive its necessary moisture, the greater part of the 20 tons of smoke daily sent into the atmosphere of Leeds would continue to float forever in the ocean of air around us. That atmospheric dust is gradually delivered back to the earth is, however, poor consolation to us who suffer from town fog. Just as well might we promise to the drowning man a future abundant supply of air, for the lack of which he will in a few moments have ceased to live. A lecture is neither a fable nor a fairy tale and

need point no moral; but before bringing it to a close I have one suggestion to make. Those who have followed my lectures thus far will, I am confident, agree with me as to the serious importance of this subject of town air from the nature and extent of air pollution here in the town of Leeds, its marked effect upon the life of its citizens, especially of its working population, and its effect on vegetation, and indirectly, therefore, on the possibility of purifying the atmosphere.

Our medical officers in their weekly or quarterly returns usually include a certain amount of interesting and useful information about the weather, the temperature, and the barometer readings. These weather statistics have their value in relation to epidemic and endemic disease. I do not wish to underrate them. But how vastly more important is it for us to know the extent of our air pollution. And the matter carries still further weight from the fact that the weather is beyond our control, but the purity of our town atmosphere lies in our own hands. We want our experimental stations, our watchtowers, within and outside the town, where the condition of the atmosphere may be constantly tested, where with every new progressive step in air purification we may mark the effect on the atmosphere as well as on the health of the citizens. This need be no costly undertaking. Three or four intelligent lads of 15 or 16 with a good board-school training under the control of the city analyst or other competent chemist could manipulate all the necessary apparatus, which in itself, as you have seen, is simple and inexpensive.

One word more. Ruskin, as Collingwood in his biography relates, kept for fifty years careful account of the weather and effects of cloud. He noticed that since 1871 there had been a prevalence of chilly wind, but different in its phenomena from anything of his earlier days. "The plague wind," so he named it, "blew from no fixed point of the compass, but always brought the same dirty sky in place of the healthy rain cloud of normal summers."

This "eclipse of heaven" Ruskin regarded, if not as a judgment, at all events as a symbol of the moral darkness of a nation. In whatever light we are inclined to regard Ruskin's opinions, he has ever been admittedly a most careful and trustworthy student of nature. May not this "eclipse of heaven" be the effect of our town smoke, which we know is perceived at a radius of 10 miles, and probably extends many times that distance from some of our large towns. I can not doubt that the total effect of the millions of tons of smoke sent yearly into the atmosphere of the United Kingdom must modify in some degree the character of our climate.

We ought, however, to take courage from the fact that, if we can not get pure country air in town, a vastly purer atmosphere is within easy reach if we would only grasp it. Then we may begin to think seriously

of beautifying our buildings and streets and squares, and of realizing the ideal town described in my first lecture.

Lecture 4.—The Germs of the Air.

Until the beginning of the present century, physical science directed the minds of philosophers mainly toward the study of the infinitely great—the discovery of new worlds in space, the study of universal gravitation, and the measurement of the velocity of light. The present century has illumined a new path in the Dark Unknown. The science of to-day is essentially the science of the infinitely small. Dalton's atomic theory, a theory of the invisible atomic structure of matter, is the foundation of modern chemistry and physics. The germ theory of disease, a theory which involves the existence of the microscopic living matter dwelling within and around us, is the basis of modern pathology and surgery. It is to these minute organisms that I have now to direct your attention.

The discovery of these living particles, particles so small that it is probable that many of them defy the scrutiny of the most perfect microscope, originated in the study of a very ancient process, the process of fermentation.

Boyle, in the seventeenth century, in his "Essay on the pathological part of physik," with that almost prophetic clearness of vision which marked his conclusions, wrote as follows: "And let me add that he that thoroughly understands the nature of ferments and fermentations shall probably be much better able than he that ignores them to give a fair account of divers phenomena of several diseases (as well fevers as others) which will, perhaps, be never properly understood without an insight into the doctrine of fermentations."

The making of wine and the brewing of beer have been practiced in historic and prehistoric times. Theophrastes, who lived in Egypt B.C. 400, described beer as the "wine of barley." Noah, we read, "planted a vineyard and drank of the wine which maketh glad the heart of man," and one or both of these processes is practiced by nearly every nation, civilized and uncivilized, at the present day.

If the grape is crushed and left to itself at a moderate temperature it begins to froth. After a few days its sweetness, which was due to sugar, has gone and the juice has acquired a slightly burning taste. It now contains no sugar, but alcohol. If barley is moistened and allowed to germinate and the germination suddenly stopped by roasting the grain, the barley has a sweetish taste. It is now called malt. The constituents of the barley have been changed; a new substance has been formed, viz, diastase, a substance which has the peculiar property of converting the starch of the grain into sugar as soon as the grain is steeped in water. A little of this sugar has already appeared

in the malt, and to this its sweetness is due. The malt is now steeped in water for a short time, the water is boiled and rapidly cooled, and this extract is called "wort." If a little yeast or brewer's barm is added to the wort it begins shortly to bubble up, and at the same time a white scum forms. This scum is yeast, which by the end of the process is four or five fold the quantity of the original yeast. The sweetness of the wort has gone, and in the place of sugar it now contains alcohol. The making of wine and the brewing of beer are very similar processes. In brewing, the brewer adds his ferment; in wine making, the ferment is with the grape. "What has been done consciously by the brewer has been done unconsciously by the wine grower."[1] The nature of this ferment—the yeast—was first examined in 1680 by Leuwenhoek in the early days of the microscope, and he found that it consisted of minute globules. More than a century and a half elapsed before our knowledge of these globules was materially increased, and then in 1835 Cagniard de la Tour, in France, and Schwann, independently, in Germany, on carefully observing these globules noticed that they threw out buds, that they were in fact a low form of plant life.

Here you see (fig. 30) the yeast plant in its various stages of growth, the single spherical cell, then the bud growing and developing, and finally separating from the mother cell and so forming a new yeast plant. If the liquid is undisturbed these cells remain together and appear to ramify like the lobes of a cactus leaf.

It was at this point that Pasteur took up the subject. I could easily devote a lecture—nay, a series of lectures—to the researches of this distinguished chemist, which are models of scientific acumen and experimental skill.

It may suffice to say that he incontestably established the fact, in spite of much opposition on the part of scientific men, that the conversion of sugar into alcohol is brought about, although we do not yet know how, by the living yeast cell during its life in the liquid. As long as yeast is excluded no fermentation takes place. How comes it, then, that wine ferments spontaneously, whereas beer does not? This question was also answered by Pasteur. The germs of the yeast plant are contained in the dust of the air which settles upon the grape. I will now show you on the screen the apparatus and explain the method by which Pasteur solved the problem.

The flask *A* (fig. 31) has two necks, the one is drawn out to a point, and sealed, the other is also drawn out to a fine tube and bent, as shown in the figure. Although the end is turned up and open, no dust can enter. The point is inserted through the skin of the grape, as shown in *B* in the enlarged drawing of the same. After insertion the point is broken and the juice sucked into the flask by aspirating at the open bent limb. The point was then fused; in this way the dust from the outside of the grape was excluded and no fermentation took place.

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[1] Professor Tyndall.

LOUIS PASTEUR.
(1822–1895.)

Yeast would also find its way into the brewer's wort; but this liquid is neutral and not acid like grape juice and is capable of nourishing other germs, which can not convert sugar into alcohol, but yield acid substances, as the brewer not unfrequently finds to his cost, when occasionally such germs find their way into the fermenting vat.

By adding pure yeast, the yeast being first in the field establishes itself generally to the exclusion of other forms of life just as soil sown with wheat will produce wheat and not weeds, as it would otherwise do. The souring of beer and wine next claimed Pasteur's attention and he found that certain much more minute forms of low vegetable life called bacteria or microbes had the property of converting sugar into acids.

Here are some of these much more minute germs which are found in bad beer growing in bead-like filaments side by side with the yeast cells (fig. 32). The study of the microbes led Pasteur to the discovery of a process for preventing wine from turning sour. He found that a temperature below the boiling point of water destroyed these germs. After the wine is bottled a short immersion in hot water will kill the germs without materially affecting the flavor of the wine, and the wine will undergo no change on keeping. This process is known as "pasteurization." The production of vinegar from beer and wine was found to be due to the microscopic ferment, which converts alcohol into acetic acid, known as mycoderma aceti or acetic ferment, and which, as just stated, is found in sour beer.

The germs of all these forms of vegetable life are found in the dust of the air. This dust when not stirred up gradually settles, and when the germs chance to sow themselves in good ground, with the temperature neither too hot nor too cold, they will immediately begin to grow and multiply, generally at a prodigious rate, living on the material and bringing about its conversion into new and usually simpler forms of matter.

The inference that putrefaction has a similar origin naturally suggests itself. We know that meat during warm weather rapidly becomes putrid. Such a piece of meat examined under a powerful microscope will be found to be swarming with bacteria. Now, it is found that exposure to the temperature of boiling water if sufficiently prolonged—for some bacteria die harder than others—will kill them, and the freezing temperature will render them inactive, though without always destroying them; that certain so-called antiseptics, carbolic acid, corrosive sublimate, boric acid, etc., act as poisons and kill them. We can recall for ourselves a number of instances where one or another of these methods is employed to prevent putrefaction and decay. Meat and milk are preserved by heating them in air-tight tins. In summer time milk may be kept from turning sour by boiling it, and game preserved untainted by parboiling it. In a similar manner cool larders and refrigerating chambers retard or prevent putrefaction.

Perhaps one of the happiest and most fruitful results of the study of this engrossing subject has been the antiseptic treatment of disease, first introduced by Sir Joseph Lister. In speaking upon this subject, the late Professor Tyndall said:

Consider the woes which these wafted particles during historic and prehistoric ages have inflicted upon mankind; consider the loss of life in hospitals from putrefying wounds; consider the loss in places where there are plenty of wounds, but no hospitals, and in the ages before hospitals were anywhere founded; consider the slaughter which has hitherto followed that of the battlefield, when these bacterial destroyers are let loose, often producing a mortality far greater than that of the battle itself; add to this the other conception that in times of epidemic disease the selfsame floating matter has mingled with it the special germs with produce the epidemic, being thus enabled to sow pestilence and death over nations and continents—consider all this and you will come to the conclusion that all the havoc of war ten times multiplied would be evanescent if compared with the ravages due to atmospheric dust.

If after disinfecting by killing the germs we can exclude the air, or the dust of the air, the most putrescent substances may be kept indefinitely without the slightest indication of putrefaction. Both Pasteur and Tyndall have established this fact in the most convincing manner, the former by allowing calcined air (that is, air passed through a red-hot tube) to come in contact with a highly putrescible substance like beef extract, the latter by giving the substance access to dust-free air in a chamber similar to one shown in my last lecture, the purity of the air being tested by a beam of light. I have referred to the relations of dust to epidemic diseases in the paragraph quoted from Professor Tyndall. This relationship is perhaps not quite so obvious as that which has been found to exist between the germs of the air and festering wounds.

To discover this relation, we must again seek it in a research of Pasteur—one of the noblest services that any man has rendered to his country. The outline of the story is briefly told.[1]

For fifteen years, a plague raged among the silkworms in the silk-growing district which lies to the southeast of France. From 130,000,000 francs, which was the value of the silk produced in 1853, it had dropped to 30,000,000 francs in 1862, and there was no sign of abatement of the disease.

In 1863 the French minister of agriculture offered a reward of £20,000 to anyone who should find a remedy. The district which suffered most was Alais, the country of Pasteur's friend, the chemist Dumas, who wrote to Pasteur, "I put a great price upon seeing you fix your attention on the question which interests my poor country. The misery there surpasses all imagination." In June, 1865, Pasteur gave up his post at Paris and with his wife left for Alais. The disease of the

[1]A fuller account may be found in Tyndall's "Dust and Disease."

silkworm was characterized by the appearance of black spots. It showed itself, moreover, in the stunted and unequal growth of the caterpillars, in the languor of their movements, fastidiousness in regard to food, and premature death. The black spots which appeared through the transparent skin of the silkworm had been examined and proved to be living corpuscles. These gradually took possession of the intestinal canal and spread, finally filling the silk cavities so that the worm when its appointed time came went automatically through the process of spinning, but without producing any silk. This was already known when Pasteur came upon the scene. By careful and constant use of the microscope he followed the life of these fatal corpuscles.

The life of the silkworm is like that of any ordinary caterpillar. When hatched from the egg the worm, which is not much larger than a pin's head, begins to feed and grow, casting his skin from time to time when his coat gets too tight until, having attained a length of almost 2 inches, he suddenly stops feeding and, having found a suitable spot, he begins to spin his silk web around him.

Within the cocoon he remains dormant for a time in the chrysalis state, and then in the form of the moth makes his way out of his silk prison. The puzzle which had baffled previous investigations was this: The eggs and the worm might appear sound and healthy and yet produce in the one case diseased worms and in the other, although spinning their silk cocoons, produce diseased moths or eggs. Pasteur proved that "the corpuscles may be incipient in the egg and escape detection, germinal in the worm and baffle the microscope." As the worm grows the corpuscles grow; in the chrysalis they are more distinct, and in the moth they invariably appear. A diseased moth then lays infected eggs which, owing to the minuteness of the corpuscles, appear healthy. Moreover, a diseased worm may infect a healthy one. Feeding together, corpuscles are transferred from the diseased to the healthy worm, and the infected worm, without immediately showing signs of disease, may spin its cocoon and eventually lay its eggs; but the eggs are all tainted. Instead, then, as silk growers were in the habit of doing, of selecting the eggs for the next year's growth from the moths which had survived the most successful cocoons, the microscope was brought to bear on the moths when the presence of these diseased corpuscles was invariably made evident. This is the practice now adopted by all silk growers, and numbers of women skilled with the microscope examine each moth as it emerges from the cocoon.

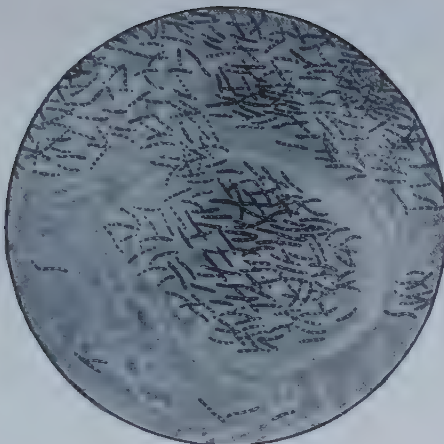
Here we have, then, the first distinct connection between living germs and the cause of disease, of infection, and of hereditary taint. The constant strain of microscope work, which restored to France her silk industry, produced partial paralysis from which Pasteur never quite recovered.

It would be easy to multiply examples to which this great discovery has given rise. Tuberculosis, diphtheria, wool-sorter's disease, leprosy, cholera, typhus, and tetanus have been traced to the existence of microscopic living matter (figs. 33, 34).

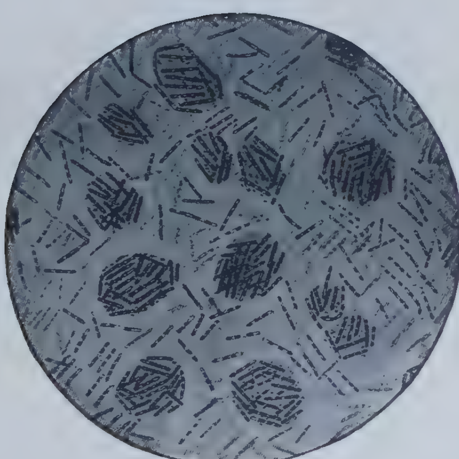
I have taken you over this little bit of history in order to indicate the importance of knowing the number and character of the almost invisible living germs of the air, and this must be my apology for introducing a subject which may seem to lie a little outside the special topic of town air.

If we examine dust under a powerful microscope, we find that it consists of a variety of things, which I enumerated in my last lecture. Now, the greater part of this dust, although heavier than air and settling rapidly where the air is still, is so very fine as to be almost invisible except when illuminated by a bright beam of light. Can we gain any idea of the weight of these little particles? In my second lecture, I told you that the weight of dust in 100 cubic feet of air in town is over 1 milligram. In my last, that in the parish churchyard 3,638,000 dust particles were contained in 1 cubic inch. From this it may be calculated that about 40 million million dust particles weigh 1 grain and would occupy a space of 240 cubic yards, or a space measuring rather over 6 yards each way.

What proportion of the dust consists of spores, pollen, and fungi, and what proportion do the bacteria form? The amount of living matter in the air has been carefully investigated for a long period of years by M. Miquel, of the Observatory of Montsouris, situated on the outskirts of Paris. This careful experimenter has directed his attention mainly to determining the number of vegetable spores, fungi, and microbes in the air in various places and at various seasons of the year. He has determined the amount of vegetable matter and microbes in the streets, bedrooms, and living rooms of Paris and in the environs. He has drawn samples of air from the sewers of Paris, and from the top of the Pantheon, high above the town. He has examined the street dust, the dust of rooms, of the soil in the country, and in graveyards—in short, the dust of all possible places where disease germs might lie. Anyone who has leisure to take up the book "Les Organismes Vivants" can not fail to be interested in the results of so much laborious work and of so many carefully recorded facts. It would take too long and carry me beyond my subject, if I gave even a brief outline of these results; I must limit myself to town air and the minute organisms which inhabit it. The vegetable spores and fungi we may pass over briefly. This slide (fig. 35) represents the most common forms met with at the Montsouris Observatory.



33a.—Bacillus of tuberculosis. ×1500. (Crookshank.)



33b.—Bacillus of leprosy. ×1500. (Crookshank).

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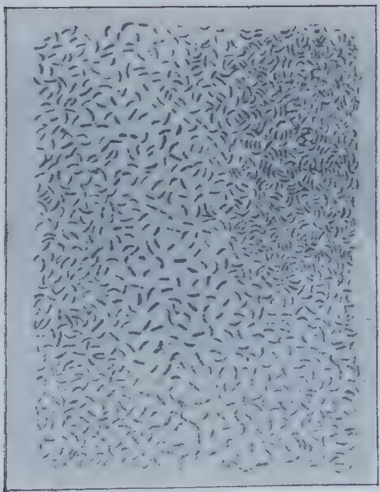
33c.—Typhus bacillus. (Schenk.)



33d.—Cholera bacillus. (Schenk.)

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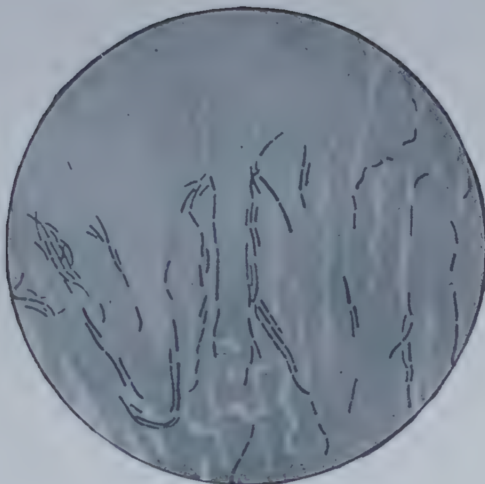
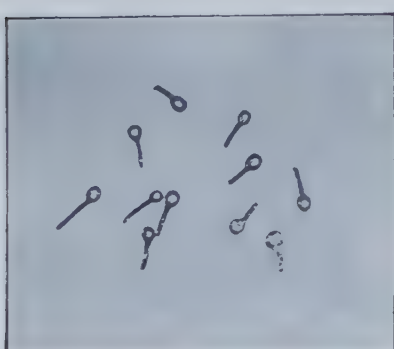


34*a*.—Bacillus Anthracis (the microbe of wool-sorter's disease). ×500. (Crookshank.)



34*b*.—Bacillus of Tetanus. (Crookshank.)

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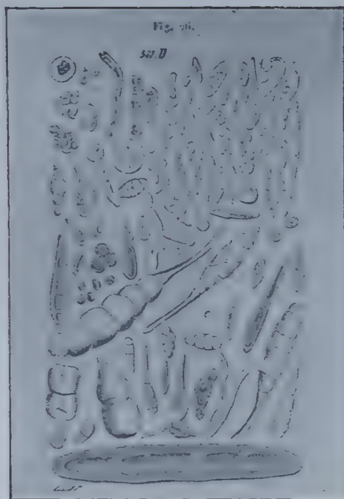
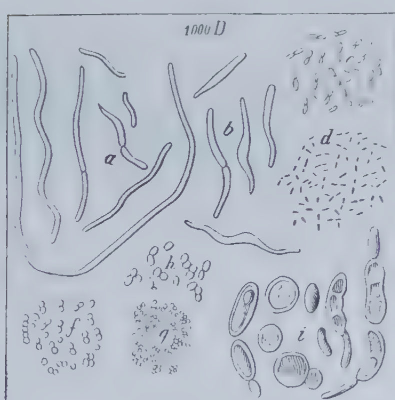


35.—Atmospheric microbes.

a, algae; *b*, cells of cryptogams; *c*, spores of cryptogams. ×500. (Miquel.)



36.—Atmospheric microbes.

a b, vibrios; *c d*, bacteria; *f g h*, micrococci; *i*, torulae. ×1000. (Miquel.)

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And the next table the average number throughout the year for the years 1878 to 1882 in 1 cubic foot.[1]

January	200	July	786
February	200	August	677
March	155	September	450
April	212	October	406
May	346	November	252
June	992	December	200

The average for the country is 200 and for the town 1,000. This refers to Paris, where there are plenty of beautiful parks and where trees line the larger streets. Where vegetation is nearly obliterated, as in the city of Leeds, the number will probably fall much below that of the country.

We now come to the much more minute inhabitants of the dust—the microbes or bacteria. Here are some of the commoner forms as seen under a powerful microscope (fig. 36).

There are globular and elongated forms, twisted filaments, spherical dots, and short, straight rods. Yeast cells, too, are often met with. They rapidly reproduce; the parent cell in the case of bacteria dividing into two or more new cells, and these again undergoing subdivision.

It may interest you to know how these almost invisible germs can be counted. Although the germ itself is only visible under high magnification, if the germ falls upon nutrient material it will soon produce a family circle readily visible as a spot of mold. One of the methods, which has been introduced by a German bacteriologist named Hess, is represented in the following diagram (fig. 37).

It consists of a glass tube coated with a nutrient jelly. The tube is first rendered sterile by heat, and then a measured volume of air is slowly aspirated through it by the aid of two bottles containing water, which can be alternately lowered and raised. The tube is then placed under the best conditions for the growth of the germs and excluded from the dust. Where a germ has fallen a spot of mold will soon appear, and such spots mark the residence of the original single germ.

The following slide (fig. 38) represents the appearance produced in the tube in three experiments made in a schoolroom: No. 1 experiment was made before the school assembled, the second in the middle of the day, and the last when the school closed.

One is struck by the great variety of these minute beings, and the difficulty of distinguishing them is increased by the fact that they appear to vary in shape with the nutrient material upon which they grow. If they are fed on beef tea they may take a different shape to that produced by a diet of agar jelly. There seems very little doubt that the number of species is very large, and very little is known, moreover, of their functions. It is certain that at least a few produce disease. It is equally certain that a large number, when inoculated into animals, are harmless. That these harmless ones serve a useful purpose in carrying on putrefactive change, acting as scavengers for the world's

[1] Miquel.

refuse, seems not unlikely; but the subject is still in its infancy, and one upon which, no doubt, fresh light will fall as bacteriological research progresses. The following table gives the proportion of dust particles, spores, etc., and bacteria in a cubic foot of town and country air:[1]

	Average total dust particles.	Spores, etc.	Bacteria in 1 cubic foot.
Country	864,000,000	200	2
Town	6,000,000,000	1,000	20

The numbers represent averages throughout the year, but this includes considerable variations, which occur at different seasons of the year.

The shaded portion in the diagram (fig. 39) represents the number of bacteria, and the dotted line the temperature during the various months of the years 1879–1882.

The number does not appear to vary proportionately with change of temperature; but if we compare the rainfall with the number of microbes we see at once a rapid diminution. The rain evidently carries them down to the earth. But they are far from being destroyed. The moisture seems to assist reproduction, for we find a rapid increase directly after rain. If drought is long continued the number falls off again. They die. Here, again (fig. 40), the shaded portion represents the number of bacteria, and the line the rainfall during the year 1879–80.

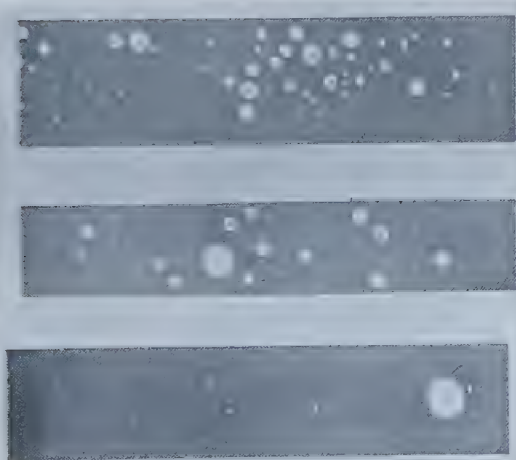
The number of microbes in the streets of Paris is on the average about 21 to 22 in the cubic foot, and this agrees with that found by Professor Carnelley in the streets of Dundee, viz. 20 in the cubic foot. Outside of Paris the number falls off to 2 whereas, in dirty, one-roomed houses Carnelley found 3,430 and Miquel in a neglected hospital ward 3,170 in the cubic foot. The effect of population in increasing the number of microbes may be represented by the following rough map of Paris (fig. 41), in which the number of microbes in a cubic meter of air observed at Montsouris is marked against the arrow denoting the direction of the wind. From this it will be seen that the largest number occurs when the wind blows across the town and the smallest number when it comes direct from the country—that is, from the south.

The number, 21 to 22, for the streets of Paris is a rough average. In dry, dusty weather, following rain, the number may rise to 150. Directly after wind and rain it may fall to an average of 6 per cubic foot.

We can not be surprised that the washings of the air by rain, accumulating in the mud of thoroughfares, should be the gathering ground for microbes. The mud of streets is more than this. It provides food for their growth. It is the great source of bacterial propogation. When we open our windows to let in fresh air on a dry, windy day, we are welcoming these small visitors. The number of microbes in a grain

[1] Miquel.

37.—Apparatus for counting microbes in the air.



38.—Microbes in air of schoolroom.

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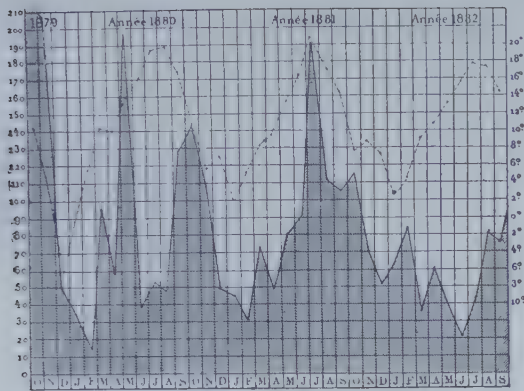
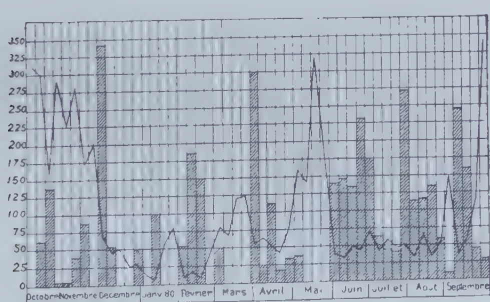
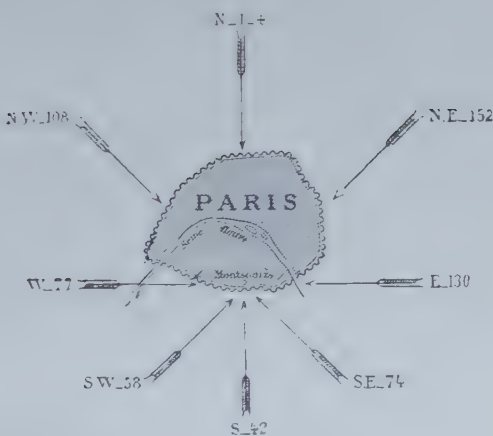


39.—The variation of the number of bacteria with the temperature. 1880–1882. (Miquel.)



40.—The variation of the number of bacteria with the rainfall. 1879–1880. (Miquel.)

THE AIR OF TOWNS.



41.—Influence of the direction of the wind on the number of microbes collected at Montsouris. (Miquel.)

THE AIR OF TOWNS.

of dust from the streets of Paris was found to be 84,240, nearly double that contained in similar dust obtained on the outskirts of the town.

Can we be astonished at finding domestic dust nearly as pregnant with living matter as that from the street, which, according to Miquel, is 64,000 in the grain? It might appear judicious to keep our windows closed under such a siege, but a moment's reflection will, I think, solve the difficulty. We do not know to what degree these microbes are mischievous. We do know to what extent fresh air is necessary to health. Let us admit air, but keep our dwellings, as far as possible, free from dust. Microbes settle rapidly in still air, and we have only to rise a few hundred feet above the ground level to prove it. On the same day Miquel found on the top of the Pantheon less than 1 on the average in the cubic foot; at Montsouris $1\frac{1}{2}$, and in Paris streets about 12. At a height of almost 1,000 feet the number is about one-sixteenth of that on the ground level. On the high Alps, as Pasteur and Tyndall have shown, they disappear completely. If we want fresh air we know where to go. We must climb the hilltops. An idea of the great army of microbes which are constantly on the march out of a big town may be gathered from the number computed for Paris, viz, 40,000 million daily, a number which may be graphically expressed by supposing all the microbes in 11 gallons of soup, in full putrefaction, to arise and march away.

Ladies and gentlemen, my task is at an end. There is much that I have left unsaid in the course of these lectures. I should like to have alluded to the possibility of reducing domestic smoke, of the smoke of our warehouse and office buildings, of the better utilization of coal, and of the use of gas for household purposes. I should like to have said much more on the important subject of ventilation of our dwelling rooms and offices. These matters must be left for a possible future occasion. I should, however, be content with the result of these four lectures if you carried away, immovably impressed upon your minds, the fact that pure air is indispensable to health. Do not let us resemble people sitting in a close room who, by gradually becoming accustomed to their surroundings, grow oblivious to the polluted atmosphere they are breathing and the poison which they are slowly absorbing.

A chairman at a lecture which I once delivered on a similar topic to this said at the close: "I think the lecturer makes too much of these invisible things in the air. We seem to keep alive in spite of them." But we don't want merely to keep alive. We want to live without the burden of trying to keep alive. What future is there for a country two-thirds of the population of which inhabit towns, and of whom Mr. Acland said "a great deal of this work of the towns, which necessitated strong and healthy men, was done by those who had been brought up in country homes and not in those of towns."

As I have already said, impure air, no matter whether it arises from bad gases, soot, or disease germs, is injurious to health. If we are

attacked by a wild beast we do not remain passive. We prepare to kill it or to run away. And if the health of a town population is slowly undermined, as it assuredly is, by causes which we can compass and prevent, as we can not run away to pure air, we must face those causes and stamp them out. There is much that the local authority can and ought to do, and which we should collectively see is done. But there is much that we as individuals can do ourselves. It is a duty to ourselves that these things should be done. It is equally a duty to the young and growing generation.

APPENDIX I.

A RAPID METHOD FOR THE ESTIMATION OF CARBONIC ACID IN THE AIR.

(1) *A standard solution of limewater.*—Pure water is left in contact with slacked lime until saturated. The clear decanted liquid is diluted with ninety-nine times its volume of distilled water. Make 1 quart or 1 liter.

(2) *Phenolphthalein solution* is made by dissolving one part of phenolphthalein in five hundred times its weight of dilute alcohol [equal volumes of pure alcohol and water]. Make 3 ounces or 100 cubic centimeters.

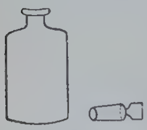


FIG. 1.

(3) *A 20-ounce stoppered bottle* with (preferably) a hollow stopper marked to hold 3 drams or 10 cubic centimeters.

A sample of air is taken by blowing air into the clean stoppered bottle (fig. 1) with bellows. Six minims or one-third of a cubic centimeter of the phenolphthalein solution is then added, and the measured volume of limewater is run into the hollow stopper.

The limewater is poured into the bottle, the stopper inserted, the time noted, and the contents vigorously shaken. If the red color of the liquid disappears in three minutes or less the atmosphere is unfit for respiration.

The stock of limewater should be kept in a bottle (fig. 2) furnished with a tap and coated within with a film of paraffin, and in the neck an open tube should be inserted containing pieces of caustic soda or quicklime. The phenolphthalein solution is best measured by means of a narrow glass tube passing through the cork of the bottle upon which the measured volume is marked. If the cork fits easily the liquid may be forced up exactly to the mark by pushing in the cork.

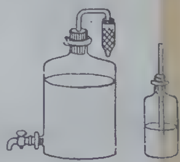


FIG. 2.

The following are estimations made in this manner compared with the results obtained by Pettenkofer's method:

Time.	Per cent volume of carbonic acid.
Minutes.	
$1\frac{1}{4}$	0.1618
$1\frac{3}{8}$	.1379
$1\frac{1}{2}$	.1279
$3\frac{1}{4}$	.07716
$4\frac{1}{4}$	.05142
5	.0464
$7\frac{1}{2}$	.0351

APPENDIX II.

I have registered by a well-known method * the total daylight on a spot on Woodhouse Moor (a high open moor lying to the northwest of the town) nearly every day during the months November, 1895, to February, 1896. The same has been done at the Philosophical Hall (near the center of the town) and at Kirkstall Road † (a busy manufacturing center). In the latter place the smoke absorbs about one-quarter of the total daylight. The following are the results obtained. To economize space the results for each week are added together:

Light tests.

A comparison of the total daylight in different parts of Leeds.

Year 1895-96.	Woodhouse Moor.	Philosophical Hall.	Kirkstall Road.
July 1-7	Not recorded.	78.30	....
July 8-14	Not recorded.	88.30	83.60
July 15-21	Not recorded.	61.70	60.60
July 22-28	Not recorded.	65.30	58.50
Nov. 10-16	22.94	Not recorded.	20.61
Nov. 17-23	15.92	Not recorded.	12.25
Nov. 24-30	10.20	Not recorded.	6.10
Dec. 1-7	10.90	Not recorded.	10.34
Dec. 8-14	18.30	Not recorded.	7.17
Dec. 15-21	4.50	*4.80	3.53
Dec. 29-Jan. 4	2.60	1.99	1.53
Jan. 5-11	4.65	2.32	2.51
Jan. 12-18	7.88	5.60	5.51
Jan. 19-25	8.17	5.90	5.47
Jan. 26-Feb. 1	13.66	9.02	8.04
Feb. 2-8	6.56	*7.20	*7.58
Feb. 9-15	8.28	*9.05	*10.57
Feb. 16-22	3.82	*4.40	3.26

* The six numbers marked with an asterisk are exceptions to the general rule. For some unexplained reason, the amount of light registered on these dates is greater in the smokier parts of the town than on the open moor.

* The method used was to estimate the amount of iodine liberated on exposure from a mixture of potassium oxide and sulphuric acid. The numbers represent cubic centimeters of thiosulphate solution used.

† The position would be a little to the left of the center of the view shown in the photograph of Leeds.

THE COMPOSITION OF EXPIRED AIR AND ITS EFFECTS UPON ANIMAL LIFE.[1]

ABSTRACT OF A REPORT ON THE RESULTS OF AN INVESTIGATION MADE FOR THE SMITHSONIAN INSTITUTION UNDER THE PROVISIONS OF THE HODGKINS FUND.

By J. S. BILLINGS, M. D., S. WEIR MITCHELL, M. D., and D. H. BERGEY, M. D.

In May, 1893, a grant was made from the Hodgkins fund to Drs. John S. Billings and S. Weir Mitchell "for the purpose of conducting an investigation into the nature of the peculiar substances of organic origin contained in the air expired by human beings, with special reference to the practical application of the results obtained to problems of ventilation for inhabited rooms."

For a number of years prior to 1888 the prevailing view among physicians and sanitarians had been that the discomfort and dangers to health and life which had been known to exist, sometimes, at least, in unventilated rooms occupied by a number of human beings, were largely or entirely due to peculiar organic matter contained in the air expired by these persons, and that the increase in carbonic acid due to respiration had but little effect in producing these results, its chief importance being that it furnished a convenient means of determining the amount of vitiation of the air. Recently, however, several experimenters have concluded that the organic matters in the exhaled breath are not harmful, at all events to animals, and the main object of the proposed investigation was to determine the correctness of these conclusions.

The effects produced on animals and men by an atmosphere contaminated with their exhalations, and with particulate matters derived from their bodies or their immediate surroundings, may be divided into acute and chronic. The acute effect may be death in a few minutes or hours, as shown by the results observed in the Black Hole of Calcutta, in the steamer *Londonderry*, and in many of the experiments referred to in this report, or it may be simply great discomfort, especially in those unaccustomed to such conditions.

[1] The full report is printed in Smithsonian Contributions to Knowledge, Vol. XXIX (No. 980), 4to, pp. 81.

The chronic effects include the favoring of the action of certain specific causes of disease commonly known as contagious, if these are present, and perhaps also a general lowering of vitality.

The statistical evidence collected by the English Barrack and Hospital Commission (1)[1] as to the effects of insufficient ventilation upon the health of soldiers in barracks, published in 1861, showed that men who live for a considerable portion of their time in badly ventilated rooms have higher sickness and death rates than have those who occupy well-ventilated rooms, other conditions being the same; and this has also been found to be true with regard to monkeys and other animals. It is evident, however, that in a room occupied by animals or men there are many sources of impurity besides the exhaled breath, and it is still a question whether the expired air contains substances injurious to life, excluding carbonic acid.

The widely divergent results obtained and conclusions reached by different investigators during the last ten years as to whether the exhaled breath of men and animals contains a peculiar volatile organic poison, have made it desirable to repeat and vary such experiments in order, if possible, to settle this important point. The chemical analyses of the air of overcrowded rooms, and the experiments upon animals with various proportions of carbonic acid, made by many investigators, indicate that the evil effects observed are probably not due to the comparatively small proportions of carbonic acid found under such circumstances.

Claude Bernard (2), in 1857, experimented with animals confined in atmospheric air and in mixtures both richer and poorer in oxygen than atmospheric air. A small bird placed in a bell glass of a little more than 2 liters' capacity, containing a mixture of 13 per cent carbonic acid, 39 per cent oxygen, and 48 per cent of nitrogen, died in two and one-half hours. He demonstrated that carbonic acid is not poisonous when injected under the skin of animals—as much as one liter injected under the skin of a rabbit producing no ill effects. No ill effects followed the injection of the gas into the jugular vein and into the carotid artery. An atmosphere of equal parts of oxygen and nitrogen had no effect upon an animal confined in it, while an atmosphere composed of equal parts of carbonic acid and of oxygen produced immediate death in the animal placed in it. He explains the poisonous effects of carbonic acid when respired to be due to the fact that it deprives the animal of oxygen. Similar results were reported by Valentin (3) and by Paul Bert (4).

Richardson, in 1860–61 (5), found that a temperature much higher or lower than 20° C. had the effect of shortening very considerably the lives of animals confined in an unventilated jar, and that these effects were more marked when the animals were confined in an atmosphere

[1] The numbers in parentheses refer to the bibliographical list appended to this report.

richer in oxygen than air, in which case he found that by passing electric sparks from a frictional machine through the fatal air (having previously deprived it of its carbonic acid) it was again made capable of supporting life, from which he concluded that the oxygen is "devitalized" during respiration, and that the electric spark has the faculty of revitalizing it.

Von Pettenkofer, in 1860–1863 (6), showed that the symptoms observed in crowded, ill-ventilated places were not produced by the excess of carbonic acid, nor by a decrease in the proportion of oxygen in the air; neither of these being sufficient in our dwellings, theaters, etc., to produce toxic effects. He did not believe that the impure air of dwellings was directly capable of originating specific diseases, or that it was really a poison in the ordinary sense of the term, but that it diminished the capability of withstanding the influence of disease-producing agencies on the part of those continually breathing such air, and laid down the rule, which has been accepted and taught by sanitarians for thirty-five years, that the proportion of carbonic acid in the atmosphere of inhabited places affords a safe indication as to the amount of the other impurities resulting from respiration and other exhalations from the bodies of the occupants.

Hammond, in 1863 (7), reported experiments in which he sought to remove the carbonic acid and moisture, and to supply fresh air as fast as it is needed to take the place of the carbonic acid removed, thus leaving the "organic matter" to accumulate in the vessel. For this purpose he confined a mouse in a large jar, in which were several sponges saturated with baryta water, by which the carbonic acid was removed as fast as formed. Fresh air was supplied as fast as required by means of a tube communicating with the bell jar and closed by water in the bend of the tube, which acted as a valve. As the air in the bell glass was rarefied by respiration and absorption of the carbonic acid, fresh air flowed in from without, while the arrangement of the tube prevented the air of the bell glass from passing out. The watery vapor exhaled by the animal was absorbed by two or three small pieces of chloride of calcium. The mouse died in forty minutes. The observation was repeated many times, and death ensued invariably in less than an hour. On causing the vitiated air to pass through a solution of permanganate of potash the presence of organic matters in large quantity was demonstrated.

Ransome, in 1870 (8), reported a series of very interesting investigations upon "Organic matter of human breath in health and disease." By condensing the aqueous vapor of the human breath and analyzing it by the Wanklyn and Chapman method, he found that "in ordinary respiration about 0.2 gram of organic matter is given off from a healthy man's lungs in twenty-four hours," while in the air expired by persons affected with certain diseases, he found great variations in the amount of organic matter, the amount being greatest in a case of phthisis complicated with Bright's disease.

Smith (9) employed a lead chamber in his investigations upon the question whether human lungs give off any poisonous agent other than carbonic acid. He found the pulse to fall from 73 to 57 beats per minute, and the number of respirations to rise from 15.5 to 24, as the carbonic acid in the atmosphere increased from 0.04 to 1.73 per cent during four hours. When the proportion of carbonic acid rose to 3 per cent there appeared great weakness of the circulation with slowing of the heart's action, and great difficulty in respiration. He believed that these results should be attributed to other conditions rather than to the excess of carbonic acid, because he found later that it was only when lamps became dim in an atmosphere—indicating a proportion of about 10 per cent of carbonic acid present—that the respiration became difficult.

Seegen and Nowak, in 1879 (10), believed they had demonstrated the presence of poisonous organic matter in the expired breath by passing it over red-hot cupric oxide, but the quantity found was so small that they failed to determine its exact nature and properties.

Hermans, in 1883 (11), was unable to detect any organic matter in the atmosphere of a tin cage in which several persons had been confined for a number of hours, and found that an atmosphere containing from 2 to 4 per cent of carbonic acid and 15 per cent of oxygen was not toxic.

Brown-Séquard and d'Arsonval, in 1887 (12), reported that the air expired by men and dogs in a state of health has the power of producing toxic phenomena, citing three series of experiments on rabbits where such phenomena were observed. In the first series they injected into the vascular system of a rabbit 4 to 6 c. c. of water obtained by injecting from 15 to 25 c. c. of pure filtered water into the trachea of a dog. In a second series from 6 to 7 c. c. of a liquid obtained by condensing the moisture in the exhaled breath of a man were injected into the aorta, or into a vein, of a rabbit. In the third series from 4 to 6 c. c. of a liquid obtained by condensing the moisture in the exhaled breath of a tracheotomized dog were used. The condensed liquid thus obtained was filtered and then injected either into the jugular vein or the carotid artery.

The symptoms observed were dilatation of the pupils, increase of the heart beat to 240, 280, or even 320 per minute, lasting for several days or even weeks. The temperature remained normal, the respiratory movements were generally slowed, and usually there was observed paralysis of the posterior members. Choleraic diarrhea was invariably present. Death usually took place in a few days, or at the farthest in four or five weeks. As a rule, it appeared that larger doses caused labored respiration, violent retching, and contracted pupils. A rapid lowering of temperature, 0.5° to 5° C., was sometimes observed. The appearances that presented post-mortem were much like those observed in cardiac syncope.

They believed they had discovered a volatile organic poison in the exhaled breath and the moisture condensed from it. This poison they

believed to be of the nature of an organic alkaloid, or a ptomaine not unlike Brieger's ptomaine (12[a]).

In further reports, in 1888 (12[b]), they state that none of eleven rabbits in which the condensed pulmonary vapor had been injected into the vascular system in doses of 12 to 30 c. c. survived, but of eight rabbits receiving an injection of from 4 to 8 c. c. three were living after the lapse of from four to five weeks, but were then weak. When the fluid was injected under the skin of the thorax and in the axilla, five out of seven rabbits died rapidly. The results were much the same as when it was injected into the blood. The quantity of the condensed liquid injected in these seven was 20 c. c. in one case, 25 c. c. in three cases, 31 c. c. in one case, 40 c. c. in one case, and 44 c. c. in another case. After death, considerable congestion of the viscera was noted, especially of the lungs. No appearance of embolism was noted. The brain and its membranes were congested, but without visible lesion. The condensed liquid turns concentrated sulphuric acid yellow. The poison is reduced by ammoniacal nitrate of silver solution as well as by chloride of gold. After boiling in a close vessel it is still toxic, showing that the poison is not a microorganism. The boiled lung liquid poisons with more rapidity than that which has not been sterilized, and may kill a pigeon and a guinea pig as well as a rabbit; that it may kill by being injected into the rectum or into the stomach; that a guinea pig two months old was killed within twelve hours by an injection of 3 c. c. into the peritoneal cavity. If injected into the lungs this liquid produces rapid congestion followed by true inflammation and red hepatization.

In an experiment with two dogs it was arranged that one breathed ordinary air and the second inhaled air which came from the lungs of the other. The dogs were of the same weight, 15 kilograms. The experiment continued for six hours and forty minutes. No appreciable or immediate consecutive accidents were produced.

In a second experiment the pulmonary liquid was collected from dogs through a tracheotomy tube, to exclude impurities furnished by the mouth. The air inhaled was first washed to remove dust. The moisture in the air expired was condensed, and the liquid collected in a flask surrounded by ice. At the moment of injection this liquid was filtered, and was then injected at the temperature of the laboratory, about 12° C. If the animal was kept immovable from twelve to sixteen hours, inflammation of the air passages was produced. The liquid of the first hours came from a thoroughly sound lung, and in the later hours from a diseased lung. The two were collected separately and tried separately. For 1 kilogram of the animal, for each hour, the mean quantity of fluid obtained was 0.38 gram, varying from 0.28 to 0.48 gram. It was greater in the beginning and lessened the longer the animal was kept in a fixed position. It was injected into the marginal vein of the ear of a rabbit by means of a syringe, 75 c. c. being injected. When the

injection did not exceed 40 to 50 c. c. the time occupied by the injection was from six to fifteen minutes. Experiments made by injections upon the dog were negative without exception. Experiments made upon the rabbit produced lesions, but the relation between these and the injections is uncertain.

Dastre and Loye, in 1888 (13), reported that they had exposed one dog to the expired breath of another for six hours without noting any effects. They inoculated animals with the condensed moisture of respiration, as follows:

Animals.	Quantity of fluid.	Results.
	Cubic centimeters.	
Five rabbits (each)	33 to 75	Negative.
Two guinea pigs (each)	5 to 7	Do.
Two dogs (each)	30 to 53	Do.
Two frogs (each)	2 to 3	Do.
Two rabbits (each)	50 to 190	Died.
A young dog (each)	a 30	Do.

a Of water.

They found that 50 to 70 c. c. of the condensed fluid of respiration (20 to 35 c. c. per kilogram) could be injected into the veins of the ear of a dog without producing any of the symptoms reported by Brown-Séquard and d'Arsonval. They observed one death during the injection of 190 c. c. (60 c. c. per kilogram), yet by control experiments with water they obtained a more remarkable result—a rapid death from the injection of 30 c. c. of distilled water (25 c. c. per kilogram).

Russo-Giliberti and Alessi, in 1888 (14), reported experiments confirming the results obtained by Dastre and Loye.

Brown-Séquard and d'Arsonval, in 1889 (15), reported a new form of experiment, by means of which they obtained additional evidence in support of their former statements. The new form of experiment consisted in confining animals (rabbits) in a series of metallic cages connected by means of rubber tubing, through which a constant current of air is aspirated. The animal in the last cage of the series receives air that has traversed the entire series of cages, and is loaded with the impurities from the lungs of the animals in the other cages. This animal succumbs, after a time, to the atmospheric conditions present. After another interval of some hours the animal in the next to the last cage also dies, the first and second animals usually remaining alive. They could not attribute the death of these animals to excess of carbonic acid in the atmosphere of the cages, because they rarely found more than 3 per cent of this gas in the last jar with small animals, or 6 per cent with larger animals. On placing absorption tubes containing concentrated H_2SO_4 between the last two cages, the animal in the last cage remained alive, while that in the cage before it was the first to die. They concluded from these facts that the death of the animals

was produced by a volatile poison, which poison is absorbed by the H_2SO_4, which thus saves the life of the animal in the last cage.

They stated (16) that any alkali used to absorb carbonic acid from expired air would also change the organic poison, and proposed an apparatus by means of which the organic poison should be supplied to the fresh air entering the jars by volatilizing it from fluid condensed from the expired air.

V. Hofmann-Wellenhof, in 1888 (17), found that when he injected large quantities of the condensed fluid of respiration at 12° C., instead of at 37° C.—intravenous injection—a resemblance of the results obtained by Brown-Séquard and d'Arsonval was produced. Under such circumstances he observed muscle weakness, slowing of respiration, fall of temperature, and dilatation of the pupils, though the animals remained alive. He injected ten rabbits with 6 to 30 c. c. of the fluid warmed to the body temperature, all the results being negative. Three other animals were injected in the jugular vein, one receiving 28 c. c. of the fluid, another 25 c. c. of distilled water, and a third 50 c. c. of distilled water. There was no difference in the symptoms noted in the animals. He noticed symptoms of depression only after injecting 50 c. c., or more, of the fluid. In a series of seventeen experiments with inoculations of from 30 to 50 c. c. each of the fluid, in twelve there appeared hæmoglobinuria; six of these died. As the result of his experiments, he concluded that the existence of a volatile poison in the expired air of healthy human beings has not been demonstrated by his experiments, this being a direct contradiction of the results of Brown-Séquard and d'Arsonval, as were also those of Dastre and Loye.

Uffelmann, in 1888 (18), found that there was a perceptible increase in organic matter in the atmosphere of a sleeping room occupied by several persons for some hours, increasing in amount with the length of time the room was occupied.

Lehmann and Jessen, in 1890 (19), collected 15 to 20 c. c. of the condensed fluid per hour exhaled from the breath of a person breathing through a glass spiral laid in ice. The fluid was always clear as water, odorless, and of neutral reaction. Nessler's reagent showed the presence of ammonia constantly, with good teeth but little, sometimes merely a trace, with bad teeth, more, though never more than 10 milligrams of NH_4Cl in 1 liter. Traces of HCl were also constantly found. A small sediment remained on evaporation, ranging from 39 to 86.4 milligrams per liter of fluid. This they believed to originate from the glass vessel; probably calcium oxalate. They tested its reducing power upon solution of permanganate of potash, making two control determinations. The first determination showed 3.6 milligrams of O for the oxidation of 1 L.; the second, 4.2 milligrams of O. They were unable to obtain any alkaloid reaction in the condensed fluid, or in its distillates, by means of $PtCl_4$, $AuCl_3$, KCdI, KBiI, KI, Bouchardet's reagent, K_2CrO_6, picric

acid, metawolframic acid, or phosphowolframic acid. Only sublimate gave at times an opalescence which, like the yellow coloration of the Nessler reagent, pointed to traces of NH_3. Neither could they succeed, according to the method of Würtz, in obtaining a lime or oxalic acid-free filtrate. The ammoniacal silver solution, according to Brown-Séquard and d'Arsonval's method, failed to give the desired reaction, remaining clear. They confined a man, clothed in his working clothes, in a zinc cage for about one-half an hour, then allowed a boy and girl to inhale the air from the cage. No ill effects, except increase of respirations to 30 and 40 per minute, were noticeable. They had complete negative results from inoculations of condensed fluid into animals.

Lipari and Crisafulli, in 1889–90 (20), reported results which were in accord with those of Dastre and Loye and directly opposed to those of Brown-Séquard and d'Arsonval. They could find no organic principle possessing toxic properties in the expired breath of healthy persons.

Margouty, in 1891 (21), reported the results of experiments similar to those of Hammond, and also of experiments in injecting fluid condensed from expired air into animals. His results did not correspond to those reported by Hammond, and there was no evidence of toxic properties in the injected fluids.

Haldane and Smith, in 1892 (22), published an account of experiments in which an air-tight chamber, 6 feet 2 inches high, 2 feet 11 inches wide, and 3 feet 11 inches long, was employed. Samples of air for analysis were drawn off through a tube placed in the wall of the chamber, about 3 feet from the floor. When one person remained in this chamber until the vitiation was from ten to twenty times as great as in the most crowded and worst ventilated public buildings, there was no perceptible odor or sense of oppression. Air vitiated to such an extent as to completely prevent a match from burning had no appreciable effect upon the subject of the experiment. In other experiments hyperpnœa and other phenomena produced were apparently due to the increased proportion of carbonic acid.

With rabbits weighing 1,800 grams, hematuria was produced when the amount of boiled distilled water injected passed beyond 100 c. c., and therefore 80 c. c. were taken as the maximum dose.

To obtain the condensed liquid from the lungs, a man expired through a Liebig condenser, in the jacket of which was flowing a stream of ice-cold water. The condensation liquid was collected in a flask, the bulb of which was buried in ice; and when the required amount (80 c. c.) had been obtained, it was at once injected into the subcutaneous tissue of the back. Six rabbits were thus injected, each with 80 c. c. of the fluid, with no evident disturbance of health in any of them; 80 c. c. to a rabbit corresponds to a dose of about 3 liters to a man. They also repeated the experiments of Brown-Séquard and d'Arsonval in supplying to the animals air charged with organic matter drawn directly from the lungs of other animals. Two large rabbits

were placed in an air-tight chamber and a current of air drawn through this was supplied to two young rabbits under observation; no effect was produced.

Merkel, in 1892 (23), reported an experiment in which four air-tight glass vessels, of 1½ liters' capacity, were connected by means of glass tubes, a mouse being placed in each vessel. Between the third and fourth vessels a Geissler absorption tube containing sulphuric acid was interposed. Air was now drawn slowly through the vessels by means of an aspirator, so that the second mouse breathed the air from the first, the third from that of the second, etc. The result was, just as in the experiment of Brown-Séquard and d'Arsonval, that the mouse in the third vessel died first, after sixteen to twenty hours, while that in the fourth vessel remained alive.

The conclusion is drawn that, as the fourth mouse remained alive, the death of the third can not have been due to excess of carbonic acid, or deficiency of oxygen in the air, but must have been caused by the presence of some volatile substance which is absorbed or destroyed by sulphuric acid.

The symptoms presented by the mice before death were at first restlessness and gradually increasing acceleration of respiration, afterwards slowing of respiration, and finally spasmodic, deep respirations, becoming constantly less frequent until the advent of death. The proportion of carbonic acid in the air led through the glass vessels was not poisonous; it amounted in the highest case to 1.5 per cent.

He concludes that the expired breath of healthy persons contains a volatile poison in extremely small quantities, being probably a base which is poisonous in its gaseous state, but loses its toxicity after combination with acids. His belief in the toxicity of the organic matter contained in the expired breath of human beings is based solely upon the results he obtained in the Brown-Séquard and d'Arsonval experiment.

Haldane and Smith, in 1893 (24), repeated the Brown-Séquard experiment, using five bottles, each of a capacity of 1 to 1½ liters, connected by means of tubes. A mouse was placed in each bottle, and ventilation established through the whole system by means of a filter pump, a small gas-meter being placed between the last bottle and the pump. Specimens of air leaving the last bottle were drawn off at intervals for analysis. Full-grown mice were used. The mice in the last two bottles were exposed to the full effect of the vitiated air for fifty-three hours without detriment.

In a second experiment an absorption tube containing pumice stone saturated with sulphuric acid was placed between the last two bottles. This experiment was continued for thirty hours; no serious effects were observed. The amount of ventilation furnished was from 15 to 24 liters per hour. The mice remained normal after having been in the bottle three days, and the percentage of carbonic acid in the last bottle had varied from 2.4 to 5.2, averaging about 3 per cent.

They state that these experiments, like their former ones on rabbits and man, are distinctly against the theory that a volatile poison other than carbonic acid exists in the expired air.

Beu, in 1893 (25), reported the results of experiments, made under the direction of Uffelmann, in which the condensed moisture of expired air was collected by the methods usually employed, taking the precaution to cleanse his apparatus with solution of $KMnO_4$ and distilled water, and likewise sterilizing the apparatus before it was brought into use. The saliva is collected in a Woulff bottle attached before the condenser. The amount of air expired, measured by a gas meter, was found to be 3,000 liters in eight hours, from which he collected 100 c. c. of fluid. A distinct ammonia reaction was obtained upon the addition of Nessler's reagent. Nitrate of silver failed to show the presence of chlorine.

Its reducing power upon solution of permanganate of potash showed 50 milligrams of oxygen necessary to oxidize 1 liter of fluid, or 15 milligrams in twenty-four hours, which denotes 0.0017 milligrams per liter of expired air. The alkaloid reaction with $AuCl_3$, KI, phosphomolybdate of potash, gave negative results.

He expired 500 liters through 150 c. c. of a 1 per cent solution of HCl, then evaporating to dryness on the water bath. A yellowish-brown deposit remained. This deposit, dissolved in distilled water, formed a fatty layer on the surface of the slightly yellow fluid. The whole quantity, 1.5 grams, was warmed to the body temperature and injected under the skin of the back of a white mouse without producing observable symptoms. This fluid had a distinct odor not comparable to anything.

He next confined a mouse in a sealed glass vessel, having a globe attached, with potash solution to absorb the carbonic acid; 3,200 expirations of air were conducted into the glass vessel during the three hours; no effect noticeable. In a second experiment the carbonic acid was not absorbed, the experiment lasting four hours; no effect.

He repeated the Brown-Séquard experiment, using white mice in four glass cages. The death of the animals, he believes, was due to changes in the temperature and the accumulation of moisture in the jars. He believes the protection afforded by H_2SO_4 in Brown-Séquard and d'Arsonval's experiments was due to its abstraction of the moisture from the air. An acute poisoning through the organic matters contained in the expired air he believes to be impossible, at least as not shown by anything in his experiments.

Rauer, in 1893 (26), used white mice confined in glass vessels of about 1½ liters' capacity, the bottom of which was covered with oats. The cork was perforated by three tubes. One of these passed down near the bottom of the vessel and served for the entrance of air; the second terminated just below the cork and served for the exit of air, and the third extended down to about the height of the animal, but

was usually closed; this was only used for the removal of air for its chemical examination. In the beginning thermometers and hygrometers were used in the vessels, but they were found to be unimportant and were abandoned. The whole apparatus was connected with a large aspirator.

In an experiment with five animals and a ventilation of 4 liters per hour, the carbonic acid was found to amount to 9.3 per cent after five hours. In another experiment with six animals and with a ventilation of 2½ liters per hour, he inserted four absorption tubes, with soda lime between the last two jars, and a Geissler tube containing concentrated H_2SO_4 between the fourth and fifth. The sixth animal remained alive, while the fifth died earlier than the fifth animal in the first experiment. He concludes that there is no organic poison in expired air, death being due to the excess of carbonic acid in the atmospheres of the jars.

Sanfelice, in 1893 (27), reported that he had repeated the Hammond experiment, using a flask of about 5 liters' capacity, the animal dying in six or seven hours. He is undecided as to the existence of a volatile expiratory poison, though he thinks that other factors, for instance, heat radiation, have an important influence upon the results.

Lübbert and Peters, in 1894 (28), reported that they had repeated the Brown-Séquard experiment, placing a guinea pig in each of a series of four flasks. Between the third and fourth flasks they placed a combustion tube through which the air coming from the third flask was conducted, passing over red-hot cupric oxide, to remove the organic matter. Before reaching the fourth flask, the air was again cooled by conducting it through a cylinder surrounded with ice. In this manner all moisture contained in the air was condensed. From this cylinder the air passes through a series of twelve U-tubes, each made from a piece of tubing 80 centimeters in length and of 2 millimeters internal diameter. During its passage through these U-tubes the air assumed a temperature of about 18° C. as it entered the fourth flask. The results obtained by this arrangement substantiated the conclusions they had formed from conducting the experiment in the ordinary manner, that the cause of death was traceable to the high per cent of carbonic acid. The removal of the organic matter by combustion failed to save the life of the animal in the last jar when the carbonic acid had increased to 11 or 12 per cent. After the absorption of the carbonic acid by means of soda lime the last animal remained alive. They conclude, therefore, that the poisonous expiratory poison of Brown-Séquard and d'Arsonval does not exist, but that death is produced by the excess of carbonic acid in the flasks.

Brown-Séquard and d'Arsonval, in 1894 (29), reported further experiments, and at the same time gave fuller details as to all their experiments and the apparatus employed. They had inoculated over 100 animals with the condensed fluid of respiration and believed in the truth of their former statements as firmly as ever. They could not

understand the failures on the part of the other experimenters. They emphatically reaffirm that the expired breath of man and animals contains a volatile organic poison producing the results reported by them, and that these results are not produced by excess of carbonic acid or deficiency of oxygen in the air.

From the foregoing summary of the reports of different experimenters, it will be seen that widely different results have been reported by them, but that the majority of the later investigators agree in denying that the exhaled breath of healthy human beings or of animals contains a poisonous organic alkaloid, or any poisonous product other than carbonic acid, yet in any case positive results require an explanation which shall account for the facts.

DR. BERGEY'S EXPERIMENTS.

The first experiments made by Dr. Bergey were to ascertain whether the condensed moisture of air expired by man in ordinary, quiet respiration contains any particulate organic matters, such as microorganisms, epithelial scales, etc. The test for microorganisms was made by having an adult man expire for from twenty to thirty minutes through sterilized melted gelatin, which was then preserved as a culture for from twenty to thirty days. In the first trial, six, and in the second, two colonies of common air organisms developed; but when special care was taken to thoroughly sterilize the vessels used, the result was that in two consecutive trials the gelatin remained sterile. Epithelial scales and other particulate matters were sought for by condensing the vapor of the exhaled breath and examining the product with the microscope, with and without the use of stains. In six preparations thus examined no bacteria or epithelial cells were found. This result was to be expected, since neither bacteria nor wetted particles pass into the air from the surface of fluids, or from moist surfaces, unless the air currents are sufficiently powerful to take up particles of the liquid itself in the form of spray.

Abbott (30), in his paper on sewer gas, reports some experiments made to determine the possibility of conveying microorganisms from liquid culture media by means of a current of air bubbling through such media; also by means of ordinary baker's yeast inoculated into media containing from 4 to 5 per cent of glucose. No bacteria were carried from the culture by the exploding air bubbles produced by the yeast, but a current of air equal to 3½ liters in six hours, bubbling through a liquid culture, carried with it some of the organisms in the culture.

The determinations of ammonia in the condensed fluid of expired air, the estimation of its reducing power upon solution of permanganate of potash, and its reaction with various reagents, were made with fluids collected from a healthy man, from a man with a tracheal fistula following excision of the larynx, the expired air not coming in contact with the mouth or the pharynx, and from a man suffering from well-marked

tuberculosis of the lungs. In each case the amount of ammonia and of albuminoid ammonia in the fluid was very small, the average being, in grams per liter of fluid:

	Free ammonia.	Albuminoid ammonia.
Healthy man	0.019	0.081
Man with tracheal fistula	.00046	.00036
Consumptive	.003	.0034

The oxidizable matter in these fluids, as shown by their reducing power on a solution of permanganate of potash, was determined. The average results, stated in milligrams of oxygen consumed per liter of condensed fluid, are as follows: Healthy man, 10.72; man with tracheal fistula, 13.49; consumptive, 19.34. The high average for the man with the tracheal fistula is due to a single observation, for which the figure was 24.916. Omitting this, the average for the three other observations would be 9.68.

The average for five specimens of fluid condensed from the expired air of a healthy man four hours after he had taken a meal was 11.98, while the average for six specimens from the breath of the same man half an hour after the meal was only 3.86. For two specimens from the same man collected three and a half and four hours after a meal, but just after the mouth had been thoroughly rinsed with warm water, the average was 2.49. These results indicate that the ammonia and oxidizable organic matter in the condensed fluid were, to a large extent, due to products of decomposition of organic matters in the mouth. The well-known fact that the amount of oxygen absorbed and of carbonic acid given off varies according to whether the person is fasting or has recently taken a meal, may possibly be in part due to the same cause, but the results obtained by Birkholz (31) indicate that it can only be in part. Ransome (8) reports no marked difference in the amount of ammonia, or of oxidizable organic matter, as determined by the permanganate test, contained in the fluids collected from the exhaled breath soon after a meal and in that collected from a fasting person. Beu (25) found a much higher proportion of oxidizable matter in the fluid condensed from his own breath (50 milligrams of oxygen required per liter of fluid) than was found in Dr. Bergey's experiments. His results indicated the exhalation of 15 milligrams of organic matter in twenty-four hours, the corresponding figure from Ransome's results being 20 milligrams. About 12 c. c. of fluid was collected from about 335 liters of air expired per hour, being nearly equal to the results obtained by Beu (25), who condensed 100 c. c. of the fluid from 3 cubic meters of air expired in eight hours.

Renk (32, p. 162) gives a table showing that in an average quantity of 9,000 liters of air expired in a day by a healthy man, the amount of moisture may be from 200 to 400 grams, depending on the temperature

and relative humidity of the inspired air. With air containing 50 per cent of moisture inspired at 25° C., the amount of moisture is 293 grams, or about the result given by Beu, referred to above.

Lehmann and Jessen (19) found that between 3 and 4 milligrams of oxygen were required in 1 liter of fluid to effect oxidation, and note that more ammonia was present in the fluid collected from a person with decayed teeth than in that obtained from a person whose teeth were sound. The very considerable differences in the amounts of ammonia and of oxidizable matter found in the fluid condensed from expired air by different experimenters, and by the same experimenter, in fluids obtained from the same person at different times, are probably due to several different causes and their combinations. The amount of fluid condensed per liter of expired air varies from 0.003 to 0.004 c. c. The soundness and cleanliness of the mouth and teeth influence the amount of ammonia and oxidizable matter expired. Variations in the amount of organic matter contained in the inhaled air may possibly influence the result, but this influence must be slight. Ransome's results indicate that the age, health, and vigor of the person may affect the amount of organic matter exhaled, and Dr. Bergey's experiments with the fluid obtained from the consumptive patient show that a smaller proportion of ammonia and a larger amount of oxidizable matter were present in it than in the fluid collected from a healthy man. It should be remembered, also, that it is extremely difficult to obtain accurate results in quantitative determinations of such very minute amounts of ammonia and oxidizable matters as are found in expired air, and a part of the differences in results obtained is no doubt due to unnoted differences in the details of the experiment.

The results of tests for the presence of an organic alkaloid in the condensed fluids obtained by Dr. Bergey were negative, corresponding to those reported by Lehmann and Jessen (19) and by Beu (25).

The results of attempts to condense the moisture of the air in the hospital ward were not satisfactory, and the determinations of ammonia in the fluid obtained are not comparable, except they show that the placing of a dust filter in front of the condensing apparatus causes a marked reduction in the proportion of ammonia in the condensed fluid. The evaporation equaled the condensation except on days when the external air was saturated with moisture, hence no moisture was collected on clear days, but on such days some dust particles may have accumulated in the apparatus which had no filter.

Several series of experiments were made to determine the nature of the gaseous mixtures in which small animals die with symptoms of asphyxia. The first of these series were repetitions of the experiments reported by Hammond and described above. Mice and sparrows were used. It was found impossible, by Hammond's method, to absorb all the carbonic acid produced by an animal. At the time of death of the sparrows, the carbonic acid had increased until it formed from 12.27

to 14.08, or an average for eight experiments of 13.24 per cent of the air, while the oxygen had diminished to from 3.25 to 5.61, or an average of 4.67 per cent of the air. The symptoms observed were those produced by insufficiency of oxygen, and there was no evidence that death was due to organic matters in the air. The duration of life in the animals confined was from three to six hours, being much longer than that reported by Hammond, using a slightly smaller vessel, viz. less than one hour, and corresponds to the results reported by Sanfelice (33), who found that the animals lived from six to seven hours. When the experiment was so modified that all the carbonic acid was removed from the air breathed by the animal, the animal did not die in seven hours, although the percentage of oxygen had been reduced to 18.35. These experiments, therefore, furnish no evidence of the existence of an organic poison in the expired air, but the method of absorbing carbonic acid by an alkali is said by Brown-Séquard and d'Arsonval (16) to change the organic poison which they claim to be present, and hence these experiments are not conclusive on this point.

A series of experiments was also made upon mice and sparrows to determine the time required to produce death by asphyxia when the animal is confined in a jar of known capacity, when no provision is made for removing carbonic acid and moisture, or for supplying fresh air, and also to determine the proportions of carbonic acid and of oxygen existing in the inclosed air at the time of death. In connection with these experiments, it was also sought to determine the influence which high or low temperatures of the air would have on the result.

A mouse weighing 21 grams, placed in a jar of 1,000 c. c. capacity at a temperature of 30° C., lived four hours; in a jar of 2,000 c. c. capacity a similar mouse lived seven and a half hours; in one case when the room temperature was 25.5° C., in another case when the room temperature was 5° C. In the first case, death occurred when the amount of carbonic acid was 12 and that of the oxygen 8.6 per cent of the mixture; in the second case, the proportions were 13.2 per cent of carbonic acid and 6.4 per cent of oxygen; and in the third case, 10 per cent of carbonic acid and 9.2 per cent of oxygen. There are considerable differences in susceptibility to the effects of an impure atmosphere in individual mice, but when a mouse is placed in a closed jar containing ordinary atmospheric air, the time required to produce death is usually that required to produce the proportions of carbonic acid and of oxygen indicated above, and, hence, is in proportion to the size of the jar. A mouse should live about twice as long in a jar of 2,000 c. c. as in one of 1,000 c. c., other conditions as to temperature, etc., being the same, and commencing with ordinary atmospheric air.

The duration of life in the experiments with atmospheric air in closed vessels, making due allowance for variations in the air volume, coincides quite closely with the duration of life in the Hammond experiment. The air analyses at death of the animals in the two forms of

experiment, also gave very similar results. In comparing the results it is necessary to bear in mind the differences in the size of the jars and in the weight of the animals used in the several experiments. As a general rule, the animal dies when the carbonic acid has increased to between 12 and 13 per cent and the oxygen has diminished to between 5 and 6 per cent. Is death due to the increase in the carbonic acid, or to the diminution in the oxygen, or to both?

Some data for answering this question are presented, showing the results obtained by placing animals in gaseous mixtures containing various proportions of carbonic acid, oxygen, and nitrogen. The animals experimented on were mice, rats, rabbits, guinea pigs, and sparrows. The diminution in oxygen in the inspired air was the most important factor in producing death, and so long as the oxygen is present in the proportion of 6 per cent and upward, carbonic acid may be present to the amount of 20 per cent without causing death. When the carbonic acid forms much more than 20 per cent of the mixture, say 30 to 40 per cent, the oxygen must form at least 12 per cent to preserve life.

If the proportion of oxygen in the mixture be reduced, the duration of life is shortened, as will be seen from the following table:

No.	Weight.	At beginning of experiment.			At end of experiment.			Duration of life.	Capacity of jar.
		CO.	O.	N.	CO.	O.	N.		
	Grams.	*Per cent*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Hours.*	*c. c.*
8	18	0	11.35	88.65	6.56	4.14	89.3	$3\frac{1}{2}$	2,280
9	15	0	11.35	88.65	7.43	3.58	89	$4\frac{1}{8}$	2,280
10	17	0	11.35	88.65	7.52	3.16	89.2	$4\frac{1}{8}$	2,280

In these experiments, the proportion of oxygen was reduced to about one-half of that in the normal atmosphere, and the duration of life was also reduced about one-half.

The toleration which is acquired by an animal by prolonged sojourn in an atmosphere which is gradually becoming richer in carbonic acid and poorer in oxygen, makes it impossible to compare the results as to duration of life in such experiments with the results of experiments in which the animal is placed at once in an atmosphere containing abnormal proportions of these gases, so far as the effects of increase of carbonic acid and diminution of oxygen are concerned, but death does not occur in atmospheres in which the carbonic acid does not exceed 10 per cent unless the oxygen is reduced to below 7 per cent of the mixture.

A series of experiments was made by injecting into animals the fluid condensed from the air expired by healthy persons and by a man with a tracheal fistula, from whom it was possible to obtain such fluid without contamination from the exhalations from the mouth. The injections

were made into the general circulation in rabbits, and into the peritoneal cavities of rabbits, guinea pigs, and white rats, following the methods employed by Brown-Séquard and d'Arsonval and by V. Hofmann-Wellenhof. The fluid was collected with the greatest care in a sterilized apparatus; subsequent cultures made from it indicating that it was sterile. It was warmed to about 35° C. before injection. The proportion injected, as compared with the body weight of the animals, was, in some instances, less than that used by Brown-Séquard and d'Arsonval, in others greater than the smallest quantities used by them with fatal effects.

In most of the animals no observable disturbance of health was produced, nor did this condition alter in the course of several months during which they were kept under observation. One rabbit died thirty-two days after having received an injection into its peritoneal cavity of 5 c. c. of fluid condensed from the breath of a man with tracheal fistula. The results of post-mortem examination showed focal necrosis in the liver, but no ecchymoses and hemorrhages in the lungs and intestines, such as are reported as a characteristic result of such injections by Brown Séquard and d'Arsonval. Three other rabbits which had received injections of the condensed fluid, and had remained apparently perfectly well from six weeks to seven months, were killed and careful post-mortem examinations made. The results of these examinations showed that there was no special disease or degeneration in the organs of these animals.

The results of this series of experiments are, therefore, in accord with those reported by V. Hofmann-Wellenhof, and indicate that fluid condensed from the pulmonary exhalations of man has no toxic or specially injurious effect when injected into animals, and that there is no evidence that such fluid contains an organic poison.

The attempt to collect condensed moisture from the air of the hospital ward was but partially successful, as has been stated above, and a sufficient amount of the fluid to make injection experiments was not directly obtained. To overcome this difficulty, the air of the ward was drawn over sterilized glycerin, which was then diluted with distilled water, and the product injected into animals. Three of the animals thus injected died between four and six weeks later, but the post-mortem examinations failed to show any clear connection between the injection and the fatal result. As it was shown that the fluid collected and that the dust in the ward contained several species of bacteria, including pathogenic forms, it was to be expected that more definite results would have been obtained, but the power of the cells and tissues to resist the pathogenic organisms was sufficient to prevent their action in each case, except, perhaps, in one, in which the abscess produced may have been due to pyogenic bacteria in the injected fluid.

A number of experiments were made in which animals, in a series of bell jars, were caused to breathe air which became more contaminated

with the products of respiration as it passed through the series, being a repetition of the experiments of Brown-Séquard and d'Arsonval.

In the great majority of cases, death was evidently due to the diminution in the oxygen and increase in the carbonic acid, the proportions of these gases present in the jar when an animal died being that as reported, i. e., the oxygen was reduced to between 4 and 6 per cent and the carbonic acid increased to from 12 to 14 per cent. The mode of death of the animals was similar to that observed in slow asphyxia, and the results of careful post-mortem examination and microscopic investigation do not indicate the effects of any organic poison.

The insertion of absorption tubes containing caustic alkalies between the bell jars, to absorb the carbonic acid, and of concentrated sulphuric acid, did not give results corresponding to those reported by Brown-Séquard and d'Arsonval.

The mice became habituated, to a certain extent at least, to the conditions under which they were placed, and could live in an atmosphere which was almost immediately fatal to a fresh mouse placed in it. This had already been demonstrated by Bernard. In the case of several mice, this power to resist the foul atmosphere was preserved for from three to eight days after they had been removed from the jar, so that they had a certain degree of permanent immunity. Experiments were made to see if it was possible to develop such an immunity, and the results obtained indicate such a possibility, but further investigation will be necessary to settle this important point. At present it is uncertain to what extent the immunity observed in a few mice was possessed by them before they were experimented on, or was produced by their first exposures to the vitiated atmospheres.

From the data accumulated with reference to the composition of the atmosphere in these bell jars by repeated analyses at short intervals, compared with the results reported by Brown-Séquard and d'Arsonval, it seems probable that the cases in which the last animal in the series survived some of the others, and a low percentage of carbonic acid was found in the jar, should be attributed entirely to defects either in methods of air analyses or in the apparatus, or in both. If, however, the life of the last animal was apparently saved by H_2SO_4 in Dr. Bergey's experiments, it was due to leakage in the connections from the increased resistance caused by the interposition of the absorption tube. This is an important fact, which is in direct opposition to the theory of Brown-Séquard and d'Arsonval with regard to the influence of the H_2SO_4 in the absorption tubes. The great differences in individual susceptibility of different animals must also be taken into account in considering the results of these experiments. In some mice there seems to be a very considerable immunity against the asphyxiating effect of an atmosphere poor in oxygen and rich in carbonic acid.

The duration of life of individual animals in experiments of this kind depends upon the size of the bell jars in relation to the size of the

animal, on the amount of fresh air supplied, on conditions of temperature and moisture, and on individual peculiarities of the animal; and it seems probable that variations in these factors will account for the different results obtained by different experimenters. The symptoms in the animals which died were those of death by slow asphyxia.

Microscopic examination of the organs presented a picture coinciding with the gross post-mortem appearances. In the lungs the capillaries were found to be distended with blood, occluding in many cases the lumen of the alveoli and air cells, and presenting a typical picture of passive hyperæmia. In the liver, kidneys, and spleen, as well as in the intestines, the capillaries were likewise overloaded with blood. Pathological changes were but rarely noted, and some of these, such as slight proliferation of connective-tissue elements between the tubules of the kidney, and in rarer instances, in the interlobular spaces of the liver, are such as are occasionally found in animals which have not been subjected to such conditions, and may, therefore, have existed in the animals at the beginning of the experiment. All the changes which were constantly present may properly be attributed to the action of the carbonic acid and the low percentage of oxygen in the atmosphere, interfering with the circulation and aeration of the blood. The lesions reported by Brown-Séquard and d'Arsonval as characteristic in such cases were not seen. No focal necroses or peculiar uniform degenerative changes were found. The results of these experiments, therefore, do not agree with those reported by Brown-Séquard and d'Arsonval—and furnish no evidence of the existence of an organic poison in the air expired by animals.

CONCLUSIONS.

1. The results obtained in this research indicate that in air expired by healthy mice, sparrows, rabbits, guinea pigs, or men, there is no peculiar organic matter which is poisonous to the animals mentioned (excluding man), or which tends to produce in these animals any special form of disease. The injurious effects of such air observed appeared to be due entirely to the diminution of oxygen, or the increase of carbonic acid, or to a combination of these two factors. They also make it very improbable that the minute quantity of organic matter contained in the air expired from human lungs has any deleterious influence upon men who inhale it in ordinary rooms, and, hence, it is probably unnecessary to take this factor into account in providing for the ventilation of such rooms.

2. In ordinary, quiet respiration, no bacteria, epithelial scales, or particles of dead tissue are contained in the expired air. In the act of coughing or sneezing, such organisms or particles may probably be thrown out.

3. The minute quantity of ammonia, or of combined nitrogen, or other oxidizable matters, found in the condensed moisture of human breath appears to be largely due to products of the decomposition of

organic matter which is constantly going on in the mouth and pharynx. This is shown by the effects of cleansing the mouth and teeth upon the amount of such matters in the condensed moisture of the breath and also by the differences in this respect between the air exhaled through a tracheal fistula and that expired in the usual way.

4. The air in an inhabited room, such as the hospital ward in which experiments were made, is contaminated from many sources besides the expired air of the occupants, and the most important of these contaminations are in the form of minute particles or dusts. The experiments on the air of the hospital ward and with the moisture condensed therefrom show that the greater part of the ammonia in the air was probably connected with dust particles which could be removed by a filter. They also showed that in this dust there were microorganisms, including some of the bacteria which produce inflammation and suppuration, and it is probable that these were the only really dangerous elements in this air.

5. The experiments in which animals were compelled to breathe air vitiated by the products of either their own respiration or by those of other animals, or were injected with fluid condensed from expired air, gave results contrary to those reported by Hammond, by Brown-Séquard and d'Arsonval, and by Merkel, but corresponding to those reported by Dastre and Loye, Russo-Giliberti and Alessi, Hofmann-Wellenhof, Rauer, and other experimenters referred to in the preliminary historical sketch of this report, and make it improbable that there is any peculiar volatile poisonous matter in the air expired by healthy men and animals other than carbonic acid. It must be borne in mind, however, that the results of such experiments upon animals as are referred to in this report may be applicable only in part to human beings. It does not necessarily follow that a man would not be injured by continually living in an atmosphere containing 2 parts per 1,000 of carbonic acid and other products of respiration, of cutaneous excretion, and of putrefactive decomposition of organic matters, because it is found that a mouse, a guinea pig, or a rabbit seems to suffer no ill effects from living under such conditions for several days, weeks, or months, but it does follow that the evidence which has heretofore been supposed to demonstrate the evil effects of bad ventilation upon human health should be carefully scrutinized.

6. The effects of reduction of oxygen and increase of carbonic acid to a certain degree appear to be the same in artificial mixtures of these gases as in air in which the change of proportion of these gases has been produced by respiration.

7. The effect of habit, which may enable an animal to live in an atmosphere in which, by gradual change, the proportion of oxygen has become so low and that of the carbonic acid so high that a similar animal brought from fresh air into it dies almost immediately, has been observed before, but we are not aware that a continuance of this

immunity produced by it had been previously noted. The experiments show that such an immunity may either exist normally or be produced in certain mice, but that these cases are very exceptional, and it is very desirable that a special research should be made to determine, if possible, the conditions upon which such a continuance of immunity depends.

8. An excessively high or low temperature has a decided effect upon the production of asphyxia by diminution of oxygen and increase of carbonic acid. At high temperatures the respiratory centers are affected, where evaporation from the skin and mucous surfaces is checked by the air being saturated with moisture; at low temperatures the consumption of oxygen increases, and the demand for it becomes more urgent.

So far as the acute effects of excessively foul air at high temperatures are concerned, such, for example, as appeared in the Black Hole at Calcutta, it is probable that they are due to substantially the same causes in man as in animals.

9. The proportion of increase of carbonic acid and of diminution of oxygen, which has been found to exist in badly ventilated churches, schools, theaters, or barracks, is not sufficiently great to satisfactorily account for the great discomfort which such conditions produce in many persons, and there is no evidence to show that such an amount of change in the normal proportion of these gases has any influence upon the increase of disease and death rates which statistical evidence has shown to exist among persons living in crowded and unventilated rooms. The report of the commissioners appointed to inquire into the regulations affecting the sanitary conditions of the British army (1) properly lays great stress on the fact that in civilians at soldiers' ages, in twenty-four large towns, the death rate per 1,000 was 11.9, while in the foot guards it was 20.4 and in the infantry of the line 17.9, and showed that this difference was mainly due to diseases of the lungs occurring in soldiers in crowded and unventilated barracks. These observations have since been repeatedly confirmed by statistics derived from other armies, from prisons, and from the death rates of persons engaged in different occupations, and in all cases tubercular disease of the lungs and pneumonia are the diseases which are most prevalent among persons living and working in unventilated rooms, unless such persons are of the Jewish race. But consumption and pneumonia are caused by specific bacteria, which, for the most part, gain access to the air passages by adhering to particles of dust which are inhaled, and it is probable that the greater liability to these diseases of persons living in crowded and unventilated rooms is to a large extent due to the special liability of such rooms to become infected with the germs of these diseases. It is, however, by no means demonstrated as yet that the only deleterious effect which the air of crowded barracks or tenement-house rooms, or of foul courts and narrow streets, exerts upon

the persons who breathe it is due to the greater number of pathogenic microorganisms in such localities. It is quite possible that such impure atmospheres may affect the vitality and the bactericidal powers of the cells and fluids of the upper air passages with which they come in contact, and may thus predispose to infections, the potential causes of which are almost everywhere present, and especially in the upper air passages and in the alimentary canal of even the healthiest persons, but of this we have as yet no scientific evidence. It is very desirable that researches should be made on this point.

10. The discomfort produced by crowded, ill-ventilated rooms in persons not accustomed to them is not due to the excess of carbonic acid, nor to bacteria, nor, in most cases, to dusts of any kind. The two great causes of such discomfort, though not the only ones, are excessive temperature and unpleasant odors. Such rooms as those referred to are generally overheated, the bodies of the occupants and, at night, the usual means of illumination contributing to this result.

The cause of the unpleasant, musty odor which is perceptible to most persons on passing from the outer air into a crowded, unventilated room is unknown; it may, in part, be due to volatile products of decomposition contained in the expired air of persons having decayed teeth, foul mouths, or certain disorders of the digestive apparatus, and it is due, in part, to volatile fatty acids given off with, or produced from, the excretions of the skin, and from clothing soiled with such excretions. It may produce nausea and other disagreeable sensations in specially susceptible persons, but most men soon become accustomed to it, and cease to notice it, as they will do with regard to the odor of a smoking car, or of a soap factory, after they have been for some time in the place. The direct and indirect effects of odors of various kinds upon the comfort, and perhaps also upon the health, of men are more considerable than would be indicated by any tests now known for determining the nature and quantity of the matters which give rise to them. The remarks of Renk (32, p. 174) upon this point merit consideration. Cases of fainting in crowded rooms usually occur in women, and are connected with defective respiratory action due to tight lacing or other causes.

Other causes of discomfort in rooms heated by furnaces or by steam are excessive dryness of the air, and the presence of small quantities of carbonic oxide, of illuminating gas, or of arsenic derived from the coal used for heating.

11. The results of this investigation, taken in connection with the results of other recent researches summarized in this report, indicate that some of the theories upon which modern systems of ventilation are based are either without foundation or doubtful, and that the problem of securing comfort and health in inhabited rooms requires the consideration of the best methods of preventing or disposing of dusts of various kinds, of properly regulating temperature and moisture,

and of preventing the entrance of poisonous gases like carbonic oxide derived from heating and lighting apparatus, rather than upon simply diluting the air to a certain standard of proportion of carbonic acid present.

It would be very unwise to conclude, from the facts given in this report, that the standards of air supply for the ventilation of inhabited rooms, which standards are now generally accepted by sanitarians as the result of the work of Pettenkofer, De Chaumont, and others, are much too large under any circumstances, or that the differences in health and vigor between those who spend the greater part of their lives in the open air of the country hills, and those who live in the city slums, do not depend in any way upon the differences between the atmospheres of the two localities except as regards the number and character of microorganisms.

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PHYSIOLOGICAL LIGHT.[1]

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PART FIRST.—PHOTOGENIC ORGANISMS.

One of the most curious phenomena of life is unquestionably the property possessed by certain organisms of radiating into space, as luminous vibrations, a part of the energy that animates them. It might be said that these vibrations are those of life itself, since they emanate from a living substance that dies in generating them. This light being physiological in its origin, I have called its production the photogenic function. Its study comprises one of the most interesting and most important chapters of general physiology—that branch of science which embraces the history of the phenomena of life common to animals and vegetables.

I.

The existence of the photogenic function has been demonstrated *de visu* in numerous species belonging to the two kingdoms, and it might perhaps be found in all living creatures if we possessed instruments of sufficient delicacy to detect it; but this is pure hypothesis.

In vegetables this function has been observed with certainty only in organisms destitute of chlorophyll or, occasionally, in parts deprived of the chlorophyll-making function (the yellow flowers of the French and African marigolds, of the nasturtium, and others of the same color), and therefore corresponding closely with animals as to their general nutrition. But it is only in mushrooms and white algæ that the photogenic function has been studied in a truly scientific manner.

The family of *Bacteriaceæ* includes many photogenic species, both marine and terrestrial, that form the genus *Photobacterium*. The marine *Photobacteriaceæ* live free in the sea or on the surface of fishes, crustaceans, cephalopods, and many other animals; but they do not generally become luminous until after the death of their host, and after being out of the water from twenty-four to thirty-six hours. As soon

[1] Translated from the Revue Générale des Sciences pures et appliquées, June 15 and July 30, 1894, Vol. V, pages 415–422 and 529–534.

as putrefaction appears, the luminosity which they imparted to these cadavers ceases. Some *Photobacteriaceæ* live in a state of symbiosis upon species of animals that possess a luminosity of their own (*Pholas dactylus*, *Pelagia noctiluca*). In other cases they behave like true pathogenic parasites. When introduced, either accidentally or experimentally, under the carapace of certain marine or terrestrial crustacea (*Talytres*, *Cloportes*), they develop and invade the entire body. The animal thus invaded becomes luminous, but it shortly dies. The attempts made to inoculate animals of higher organization with these pathogenic microbes have hitherto failed. Still, it is quite probable that the cases of phosphorescent urine, saliva, sweat, and even wounds, observed principally in man, have had no other cause—an important matter to definitely ascertain. Unhappily for science, examples of these singular affections, which, by the way, do not appear to be dangerous, are more rare than those of mammals that become luminous after death. Besides the phosphorescence of the human cadaver, which has been observed several times, there have occurred in butchers' stalls and slaughterhouses true luminous epidemics affecting sometimes pork, sometimes beef sometimes horse meat. In the general physiological laboratory at Lyons, a case of luminosity in the domestic rabbit has been recently studied, and from it was prepared, for the first time, a pure culture of a photobacterium of the flesh of mammals, the *Photobacterium sarcophilum* (fig. 1). This discovery has led to the elucidation of several important points in the biology of these curious parasites.

The *Photobacteriaceæ* usually have the form of an elongated sole; their length varies between 2 and 4 μ and their breadth between 1 and 2 μ[1]. Some seven or eight species, or perhaps varieties, are distinguished. Some are very polymorphous and may change into micrococci, into commas, into filaments, without ceasing to be luminous. At other times, while the form remains the same, the photogenic function may be made to disappear by slightly modifying the culture medium, and inversely, the bacteria which have been extinguished may by the same means be lighted up again even after quite a long time.

These facts show that the photogenic function is independent of the form of the creature. These microbes are readily cultivated in bouillon of gelatin peptone containing 4 per cent of sea salt. While the *Photobacterium sarcophilum* develops well in liquid bouillons, it is the first photogenic microbe which has been successfully cultivated in a fluid medium containing only substances having a definite chemical composition, such as water, glycerin, phosphates, asparagin, sea salt. It also presents a peculiarity not found in other species, and which it is well to note, because it may explain why certain pathogenic agents infect all individuals without distinction, while others attack only those which have a special, morbid predisposition. With the exception of

[1] The μ, which is the unit of length in micrography, is equal to the thousandth of a millimeter.

the *Photobacterium sarcophilum*, the *Photobacteriaceæ* are not luminous in acid gelatin peptone. That bacterium, however, does not really form an exception to the common law, but it possesses the property of secreting an alkaline substance which, by neutralizing the acid medium, permits the photogenic function to operate. It therefore creates for itself a medium where others would succumb to the influence of the environment.

The luminosity quite frequently seen in autumn in the forests on dead leaves or on fragments of young or old wood, and even in mines on worm-eaten beams, is often, if not always, due to the vegetative organs of mushrooms of quite high organization, especially certain *Hymenomycetes*, the *Agaricus melleus*, for example, whose slender filaments penetrate the ligneous tissues, forming an easily recognized, whitish network. These luminous myceliums have even been successfully cultivated. Still, I have vainly sought them on pieces of very young wood, freshly broken, that presented over their entire surfaces a steady and regular phosphorescence that in certain cases might indeed be a result of a necrobiotic alteration of the tissues or the work of microbic parasites. But the microbes found on these fragments have not produced luminous cultures, neither have those which live in symbiosis on the higher photogenic mushrooms.

In certain mushrooms at an adult age the photogenic function is well marked. The laminæ of the *Agaricus olearius*, which is quite common in Provence at the foot of olive trees, gives out a bluish light that follows the fluctuations of vitality in the mushroom. It does not reside in any specially differentiated part, but only where the spores are developed.

Luminous exotic mushrooms are quite numerous. There is known in Brazil the *Agaricus Gardneri*, in Australia the *Agaricus phosphoreus*, *candescens*, *lampas*, *illuminans*, etc., whose names indicate their singular property. Some of them give enough light to make it possible to read by means of this living torch.

It can not be affirmed that in the vegetables we have mentioned the light is the result of a secretion. It seems rather to have its origin in the protoplasm, for when a bouillon made luminous by *Photobacteria* is filtered through a porcelain tube it loses its light; it would be otherwise if the photogenic substance were really dissolved in the ambient liquid.

II.

The photogenic function is likewise widely found among very inferior animals, the *Noctiluca miliaris*, for example, to which is often due the splendid phenomena of ocean phosphorescence. Besides its envelope, some intercellular liquid, its digestive vesicles, and a flagellum, the structure of the *Noctiluca* is that of an active, contractile, protoplasmic mass, surrounding a nucleus and sending toward the internal wall

of its envelope numerous retractile and excitable prolongations. It is in this last tract that we see formed rounded granulations having a special refractive power that we shall henceforth find in all photogenic elements.

Mechanical, physical, and chemical stimuli cause the interior of the *Noctilucæ* to shine, and they then appear to the naked eye like little stars emitting a steady light. But with sufficient magnification this apparently uniform glow is resolved into a multitude of little, brilliant points or sparks that, by their form and distribution, correspond to the refringent granulations of which we have already spoken.

The photogenic function is widely distributed in the class of *Cœlenterata*. There is, it is true, but one luminous species known among the sponges, but they are numerous among the *Cnidaria* and have been well studied in the *Anthozoa* of the family of the *Pennatulidæ*.

In abyssal regions numerous polyps with horny or calcareous axes, such as *Isis*, *Gorgon*, or *Mopsea*, form veritable luminous forests, producing a truly fairy-like effect.

Among the *Pennatulidæ* the photogenic function is already localized. It has its seat in the eight cords which adhere to the external surface of the gastro-vascular cavity of polyps and zooids and extends as far as the buccal papillæ. The light originates in cells containing an adipoid material and very numerous rounded, albuminoid granulations. In these cells, as with the *Noctilucæ*, mechanical, electrical, and chemical stimuli induce a luminous explosion that is transmitted from one place to another in a very regular manner, from the foot of the polyp toward the extremity of the arms or inversely, with more or less extensive generalization, according to the intensity of the stimulus.

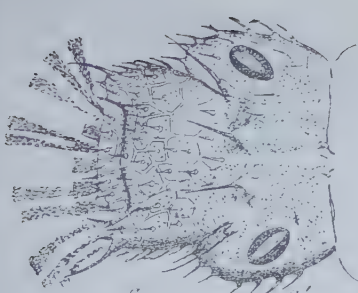
The granulations of the luminous cells seem to be formed under stimulation by a phenomenon analogous to that of the formation of crystals by the agitation of a saturated solution; at least that is what occurs in the ectodermic cells of *Hippopodius gleba*. That elegant cœlenterate is composed of a series of horseshoe-shaped segments, transparent as crystal when the animal is not stimulated, but, when the ectoderm is touched, the cells which compose it become at once opalescent or milky by the formation of a multitude of granulations, and emit a magnificent, azure-blue light. The simultaneous occurrence of these phenomena is very striking in this particular case.

Stimulation of the ectoderm also produces light in certain *Medusæ*, such as *Cunina albescens* and *Pelagia noctiluca*. In the latter the photogenic function is localized in the epithelium of the external surface, the radial canals, and the genital glands. The tesselated cells that compose this epithelium have a nucleus that is often masked by a multitude of fine and very refringent granulations, varying in color from yellow to orange.

When these cells break down they form a luminous mucus that adheres to the fingers and continues to shine for a considerable time.

1.—*Photobacterium sarcophilum.*

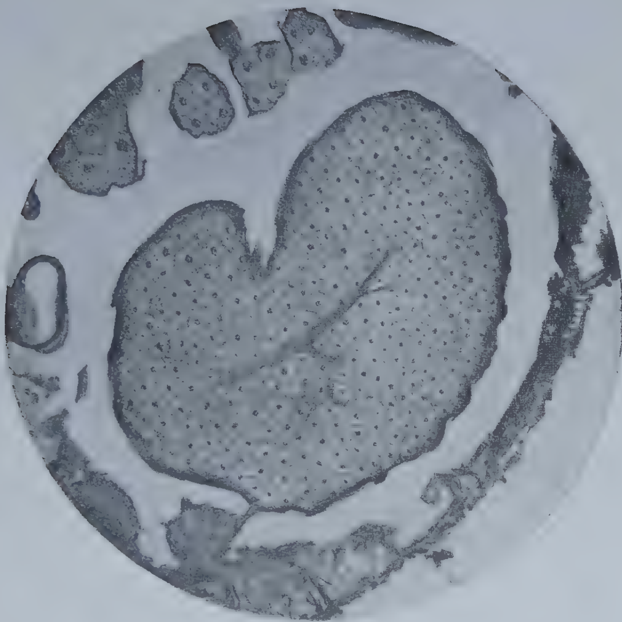
2.—*Lipura noctiluca* (magnified 350 diameters).



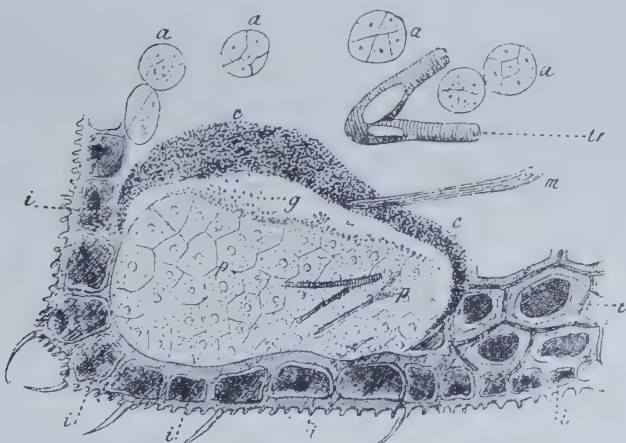
3.—Larva of *Lampyra noctiluca* in its first stage: *a a′*, ultimate and penultimate segments. On the right the luminous organs can be seen, showing through. (Magnified 65 diameters.)

5.—Section of the terminal portion of a male *Lampyra noctiluca*. *o*, Photogenic organ.

PHYSIOLOGICAL LIGHT.



4.—Section of the larval organ of *Lampyra noctiluca*.
Ramifications of the tracheal tree; in the invagination of the upper part is the muscle; the hypoderm is visible below and to the right. (A histological preparation reproduced by photography.)



6.—Section of the male organ (magnified 120 diameters).
a, a, a, a, cells of the adipose body; *tr*, trachea; *m*, muscular fascicle; *c*, chalky or radio-crystalline layer; *g*, free granulations; *p, p*, parenchymatous layer; *i, i, i, i*, cells of the hypoderm.

Many *Ctenephora*, among which may be cited the *Cestidæ*, the *Cydippidæ*, the *Beroidæ*, are luminous. The photogenic elements generally surround the costal vascular canals and sometimes also the canals of the gastro-vascular network. The embryo of *Beroes*, while yet in the egg, is luminous, and usually, if not invariably, photogenic animals transmit from generation to generation the torch of life that is never extinguished and seems to have been lighted at the very dawn of creation. In the Mediterranean the phosphorescence of the sea may be exclusively produced, as I have found, by the disintegration of coelenterates, whose bodies are sometimes thrown on the shore in great numbers.

Among the *echinoderms* the star fishes and particularly the *Brisingidæ* furnish most brilliant examples. Certain *Ophiuridæ* also emit a beautiful green light, especially when young.

Balanoglossus also produces an emerald-green light having a very beautiful effect, and this function is an additional character connecting that creature with echinoderms and worms.

In the race of *worms* the photogenic function has been observed in many wandering annelids. In the collared *Polynoe* it appears in a quite limited region of the elytra, around the elytrophore, where sections show a structure that recalls that of the luminous organs of *Pholas*, of which we shall speak further on.

In other cases the luminosity is situated in the antennæ and its existence has been shown quite early in polytrochous larvæ of polychætous annelids. Quite frequently in France there have also been found earth worms, luminous *Lumbrici*, recently placed in the genus *Photodrillus*. The species that compose it seem to be of exotic origin.

Among *articulate animals* there are a great number of species in which the photogenic function is very well developed and particularly well differentiated. It is in general localized, but often the localization seems to be displaced during the metamorphoses of the individual.

Many *crustaceans* have a luminosity of their own. It may be produced as in the *Euphausidæ*, in quite definite organs, which may have a structure so complex that they have been considered as eyes. This connection of a luminous organ appears less strange when we know the mechanism of the dermatoptic and photogenic functions in *Pholas dactylus*, and, besides, it is not impossible that the same organ may alternately or simultaneously perform two functions. These luminous globules or photospheres may exist at the same time in various parts of the body, on the claws, the thorax, the abdomen, etc. In other crustacea, such as *Mysis*, there is a brilliant circle surrounding the eye, which is actually set in a luminous, spherical cavity. The photogenic power of the eyes appears to be well developed also in *Aristeus*, *Geryon*, and *Munida*.

In the class of *Myriapods* luminosity has been scientifically investigated among the *Geophilidæ* in both sexes of *Scolioplanes crassipes*.

This species inhabits central Europe and becomes luminous in autumn. While walking or when stimulated its teguments transude a granulose, viscous liquid that emits for some moments a greenish luster. Sometimes there is no cutaneous excretion and the entire body of the animal is illuminated, except the head. The *Orya barbarica* also, which inhabits Algeria, may, under the influence of pressure and contact, discharge from its abdominal, tegumentary pores a viscous liquor, insoluble in alcohol, which solidifies rapidly, giving out at the same time a greenish-blue light. The recent study of this secretion has given me important information as to the intimate mechanism of photogeny.

III.

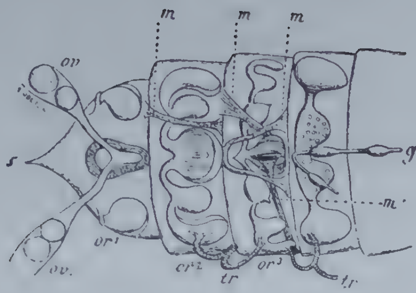
The most resplendent of all animals are *insects*, of which class the glowworm, beloved of the poets, is one of the most brilliant examples. Among the thirteen orders of this class, there are but three that contain species to which the photogenic power may be with certainty attributed, viz, the *Coleoptera*, the *Diptera*, and the *Thysanura*.

In certain continental localities the soil has been seen to become luminous, like the sand of the sea which contains *Noctilucæ*, on account of the presence of quite minute insects belonging to the order *Thysanura*, family *Poduridæ*, genus *Lipura* (fig. 2, *Lipura noctilueu*), that are not more than 2 or 3 millimeters in length. I know of but one photogenic species: this much resembles *Lipura ambulans*, if it is not identical with it, but I prefer to call it *Lipura noctiluca*.

Such species are also rare among the *Diptera*, the luminosity of the antennæ of the *Thyreophora cynophila*, a fly which lives in charnel houses, being probably the result of its habitat. The function may, however, be properly ascribed to the larvæ and nymphæ of *Ceratoplatus sesioides*. There is also found in the Sea of Aral certain species of *Chironimus*, which shine like small, dull stars. Certain analogous phenomena have been noticed in *Culex* and *Tipula*.

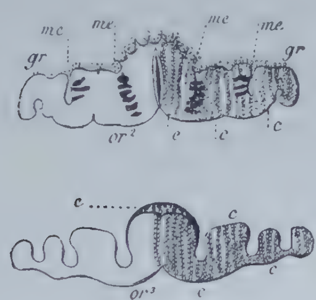
The most beautiful luminous insects are incontestably among the *Coleoptera*, confined to the two related families of *Malacodermidæ* and *Elateridæ*, of which the best known are the *Luciola italica*, the *Lampyra noctiluca* or glowworm, and the *Pyrophorus*, commonly known under the name *cucuyos*.

The photogenic property appears in the egg of the glowworm (*Lampyra*), even while it is contained in the ovary before fecundation; in the fertilized eggs it persists till the hatching of the larva. In these centrolecithal eggs we find very early the blastoderm represented by a single layer of large, polyhedric cells inclosing numerous rounded granulations and possessing the same characteristics as those which are again met with later in the luminous organs of the adult and the larva. At the moment of hatching, in the larva of the first stage, the luminous appearance shows itself in the form of two small, yellowish, ovoid bodies situated on the sides of the penultimate ring.



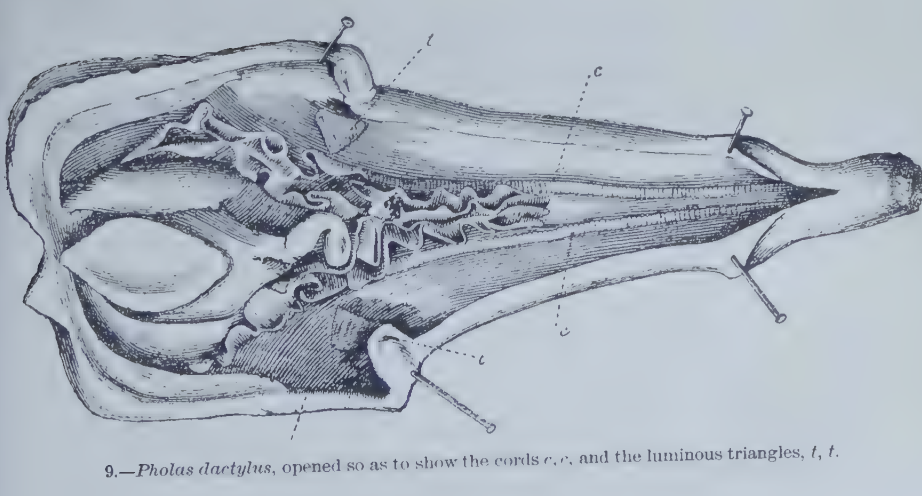
7.—Terminal portion of the body of the female *Lampyra noctiluca* (enlarged 7 diameters).

s, ultimate segment; *ov*, *ov*, ovaries inclosing eggs; or^1, or^2) or^3, photogenic organs of the female; *tr*, *tr*, tracheæ; *g*, ganglionic chain drawn forward; *m*, *m*, *m*, *m*, muscular fascicles.



8.—Female organs as in or^1 and or^2, fig. 7 (enlarged 10 diameters).

me, *me*, *me*, *me*, meatuses; *gr*, *gr*, granulations; *e*, separation between the chalky and parenchymatous layers; *c*, *c*, *c*, *c*, cells in files. (The chalky layer covers the parenchymatous layer).



9.—*Pholas dactylus*, opened so as to show the cords *c*, *c*, and the luminous triangles, *t*, *t*.

Each organ is formed by a vesicle with a transparent wall (fig. 3, luminous organ of the larva of *Lampyra noctiluca*, young specimen) which is hyaline, anhistous, filled with very granular, polyhedric cells, representing perhaps a post-embryonic blastoderm. There runs among these cells a very finely ramified tracheal arborization. When the little photogenic vesicle is compressed under the microscope there escapes from it a liquid inclosing a multitude of small, rounded, protoplasmic granulations, whose form and size recall those of certain spores; they show active movements (Brownian?).

This larval organ persists in the nympha, in the female, which preserves until adult life its vermiform appearance, and in the male (fig. 5, male organ) which in the state of a perfect insect is a winged beetle; but it undergoes certain modifications.

In the organ of the adult male, for example, there are more clearly distinguished two layers, one whitish, opaque, chalky (fig. 6, male organ enlarged), formed of very refringent, crystalloid granulations, the other parenchymatous, composed of granular, polyhedric cells. The first layer is manifestly formed by the breaking down of the parenchymatous cells, and by the change of part of the primitively colloidal protoplasm to a crystalloidal state, as is clearly shown by fig. 6, which represents a vertical section of the male organ. This section also shows some muscular fibers which are apparently for the purpose of aiding the voluntary or reflex separation of the cretaceous layers from the parenchymatous one. This is unquestionably the function of these muscles in the female.

Besides the larval organ, the female possesses two others which rest upon the abdominal wall of the two penultimate rings, these remaining transparent at this point (fig. 7, female organ). They are also composed of two layers—one, superior, chalky, crystalloidal, the other parenchymatous, formed of rounded cells arranged in regular, linear series (fig. 8).

Numerous tracheal ramifications carry on respiration in these organs, and certain anatomists, who apparently had never seen any other luminous animals, have supposed these ramifications to be of primary importance in the light-making mechanism, considering these tracheas as blast tubes for enkindling the protoplasm as if it were charcoal. But they should have at least known that the egg of the *Lampyra* has no need for such an incendiary bellows to make it shine. We will not dwell here upon the crudity of this interpretation that has nothing physiological about it and whose error we have elsewhere demonstrated.

Between the files of cells of the female organs (fig. 8, *c*, *c*), there exist numerous passages (*me*, *me*, *me*), whose width is regulated by the play of the muscles (fig. 7, *m*, *m*, *m*), so that the blood may enter the organ in greater or less quantity, thus rendering nutrition more or less active. These muscles are under the control of voluntary and reflex

centers, which explains why sensorial or psychic stimuli may affect the production of light. It is proper to add that the protoplasmic cells of insects are directly excitable, like the *Noctiluca* or the ectoderm of the *Cœlenterata.* In the *Lampyridæ*, the light-producing power is not limited to the organs in question, as the eggs become luminous in the ovary, and at the moment of molting, when the new integument is yet uncolored, in absolute darkness the entire hypoderm shows a feeble phosphorescence. Besides, embryological studies show that both in the larva and in the female nympha the photogenic organs are formed at the expense of the hypoderm.

The organic mechanism of the photogenic function in the Coleoptera is particularly easy to study in the luminous *Elateridæ*, those dazzling beetles of the tropics, and particularly in *Pyrophorus noctilucus.*

The egg of *Pyrophorus* is luminous, like that of *Lampyra*, and the little larva which comes from it also carries with it at birth the luminous source transmitted to the egg by its ancestors. In the young larva, this is single, bilobate, and situated at the junction of the head and the thorax. It contains numerous rounded granulations and emits a bluish light. After the second molting the cephalothoracic apparatus persists, and then others appear on each of the segments and a larger single one upon the last ring. These luminous spots may be lighted and extinguished successively, like the gas-burners of a stairway swept by the wind, and it is a very curious spectacle to see two of these larvæ struggling together and twisting about while emitting flashes of light. Imagine what it would be if the combatants were some meters in length.

In the adult state, *Pyrophorus* has three lanterns—two dorsal ones upon the cephalothorax and a ventral one at the junction of the thorax and abdomen. The arrangement of these organs is quite similar to that of the organs of the *Lampyridæ*, and their regulating mechanism is also very much the same. For example, by the action of small muscles the ventral organ of *Pyrophorus* opens and closes like a purse, and owing to its situation and anatomical structure it is easy to show, both by direct observation and by experimentation, that the production of the light is closely allied to the fluctuations of blood in the organ, and to a great degree independent of the play of the stigmata and the tracheæ, which are in relation with it. But why should we further discuss the essential function of hypothetical tracheal blast tubes? When the organ is isolated from the body, dried and pulverized, it still gives out light when a drop of water is let fall upon its amorphous dust—a singular combustion truly, but without blast tubes this time. In order to rapidly conclude an examination of photogenic species, I will for the present leave the study of the special mechanism of photogeny, which will be treated in the second part of this article.

IV.

Among the *Mollusca*, we find that cephalopods show luminosity only in certain rare species, though there may yet be some doubt concerning the function of certain organs supposed to be photogenic before their action was observed in living specimens. Luminosity has been noted in several molluscous gasteropods: *Aeolis*, *Hyalea*, *Crescis*, *Cleodora*, *Phyllirrhœ*, and in one lamellibranchiate, *Pholas dactylus*; it has been carefully studied only in the latter and in the *Phyllirrhœ bucephala*.

Phyllirrhœ is a naked, pisciform, Mediterranean gasteropod, having a laterally compressed, transparent body. The light is produced in peripheral, nervous cells of an ordinary form, in the cells of the central ganglia, and in tegumentary elements having very marked, dark contours and inclosing numerous rounded granulations immersed in the intracellular liquid.

The photogenic function again occurs in nervous and tegumentary cells having granular contents in *Pholas dactylus*, a sedentary mollusk that on our coast inhabits holes hollowed in the rocks, where it lives secluded, showing only the end of its siphon—a kind of double-barreled contractile tube by which it draws in and rejects the water that serves for its nutrition. The external integument of the siphon is sensitive to light like the retina of the human eye, with which it presents many analogies; it is the seat of the dermatoptic function,[1] while the internal wall of one of the two tubes of the siphon is the seat of the photogenic function. There is also as much analogy between the structure of these two walls as has been shown to exist between certain photogenic and visual organs of crustacea or fishes.

In *Pholas* (fig. 9), the light originates in the nervous, internal subepidermic coat of the aspirator siphon, and very likely, as in *Phyllirrhœ*, in the nervous elements that form a sort of diffuse ganglion; but, besides, also like that gasteropod, it appears in the tegumentary elements with granular contents, arranged, in *Pholas*, in the form of two glandular cords and two triangles situated on the inner surface of the aspirator canal. In response to various stimuli, there is formed in this canal an abundant secretion of a highly luminous mucus that communicates to the water and to bodies that imbibe it a beautiful bluish and quite persistent luminosity. Microscopical examination shows in this mucus various elements from the internal wall and from the blood, and especially certain cells with well-marked contours inclosing a liquid that holds in suspension rounded protoplasmic granulations. Other granulations of a similar nature, coming from the glandular caliciform cells of the cords and from the triangles, swim abundantly in the luminous mucus. We will study their metamorphoses in the section of this article devoted to the special mechanism of the photogenic function.

[1] See Nouvelle théorie de mécanisme des sensations lumineuses: Revue générale des sciences pures et appliquées, avril, 1890.

Among the *Tunicates*, there has been noted the *Appendicularia* of the southern Atlantic, whose urocord emits a light of a variable color, being red blue, green, and even white in the same individual. This variability in the color of the light has also been noted among the salpiform, colonial Ascidians in *Pyrosoma*, whose form is like that of a pine cone or an elongated thimble, and which is frequently found on the shore at Nice. Besides artificial stimuli, which may lead to a sudden production of light, spontaneous simultaneous movements of the colony may produce the same result. Each colonist carries a pair of photogenic organs at the base of its neck, near the upper border of the branchiæ. They are part of the external layer and entirely composed of spherical cells directly bathed by blood. A colony 0.08 centimeter in diameter, containing 3,200 colonists, will therefore present 6,400 luminous points. These little organs arise in the embryo from the ectoderm.

Salpa and *Doliola* have also been reported as luminous. In the Pacific they sometimes form streaks of light many leagues in length.

Among vertebrates, aside from cases of phosphorescence, probably of parasitic origin, found in man and some rare animals, the photogenic function has been seen only in fishes and especially in those that live at great depths. The photogenic organs may be situated in very different regions; along the body walls from the fins to the tail, near the eyes, on the branchiostegal rays, the dentary bone, and the preoperculum. By their position as well as by their organization and structure, they recall the photogenic organs of the crustacean *Euphausidæ:* like these, they have sometimes been thought to be accessory eyes and sometimes photogenic apparatus. Perhaps they may combine the two functions. They have, at any rate, ectodermic, muciparous glands connected with nerves of general sensibility, an arrangement that in no way conflicts with this view when we consider the dermatoptic and photogenic functions in *Pholas dactylus.*

This rapid survey of the world of luminous animals and vegetables shows that the photogenic function is more widely distributed than had been generally supposed, and that this beautiful phenomenon should not be considered as a mere biological curiosity. It is, like the production of electricity and of heat, a great physiological function, general in its distribution—that is to say, common to the two kingdoms of living beings.

The examples we have cited sufficiently show how independent this general function is of the organs in which it arises, and yet how simple is the cellular mechanism that produces it; this being always the same whether we consider the Noctiluca, the Hippopodius, the glowworm or its egg, etc.

We shall see in the latter portion of this article that physiological analysis may be pushed quite beyond the cell, and we shall endeavor to ascertain whether this light, transmitted from generation to generation without extinction, having doubtless been burning for thousands

of years, is reducible to a simple chemical or physical phenomenon properly so called, or whether there is reason to conclude that it depends upon vital phenomena which should be considered together in a special chapter of general mechanics—physiological mechanics or biological dynamics.

Part Second.—Special Mechanism of the Photogenic Function.

Since we employ the expression *animal heat* to designate the heat produced by animals, so we should understand by *physiological light* the light generated by the biological activity of living beings. It is distinguished from all other light by its composition, its origin, and the special mechanism by which it is produced.

I.

The color of the light may vary according to the species that produces it. In the *Photobacteriaceæ* it is sometimes silvery white, sometimes bluish or green, sometimes tinged with orange. In the same species it may also change according to the environment. In the solid bouillon of gelatin peptone the *Photobacterium sarcophilum* emits a greenish luster, which changes to a light blue in liquid bouillon.

In mushrooms, we observe similar variations; the luminosity of *Agaricus igneus* is bluish, that of *Agaricus Gardneri* dull green, that of *Agaricus olearius* and *noctilucens* white.

The same remark applies to animals, and, among these, the same individual is quite often seen to change its color from one moment to another. There have been taken from more than a hundred fathoms depth in the Strait of Skye *Pennatulidæ* or sea-pens that shine with a pale lilac light; in other cases, as in *Ophiura* and *Balanoglossus*, the light is a fine emerald green. It is bluish in *Lampyra*, white with golden glints in *Luciola*. Two lights of different colors may coexist in the same individual; certain exotic larvæ have a red light near the head and bluish lights along the body. The light may also vary with the metamorphoses of the individual. The egg and the young larva of *Pyrophorus noctilucus* give out pale blue rays, while those emitted by the adult are light green.

But what is more singular, is to see in the same animal all the colors of the spectrum succeed each other rapidly and without interruption. From all points of the stems and branches of certain Gorgonidæ, light may be seen to gush forth in jets and sprays of fire, whose luster dies away, then revives, passing from violet to purple, from red to orange, from bluish to different tints of green, sometimes even to the white of superheated iron. In the same way the *Pyrosomata* offer a very curious spectacle when heated or strongly excited. *Pyrosoma atlanticum* becomes at first red, then pink, then orange, afterwards greenish,

finally ultramarine blue. Certain *Appendicularia* have a tricolored luminosity.

Most of these variations depend upon corresponding modifications of the internal photogenic mechanism: so when the light of *Noctiluca* changes from blue to white by reason of fatigue or the somatic death of the animal, the protoplasmic granulations and the beams that they emit become at once smaller and more numerous. But the coloration of the light may also depend upon circumstances independent of its mode of production, the color of the integument, or of the blood. For example, by injecting eosin into the blood of *Pyrophorus* the light changes from its usual green color to rose.

Finally, the pale blue tint seen in many marine animals, larvæ, mushrooms, and bacteria, must in certain cases be entirely attributed to the slight intensity of the luminosity. For the same reason, a *spectroscopic examination* does not enable us to distinguish the color of the different rays that compose their spectra, but the extreme limits of such spectra, fixed by various observers, leave no doubt as to their polychromatic nature. The luminous intensity is generally only slightly increased in the middle regions of this pale spectrum.

The light of insects furnishes, on the contrary, a fine continuous spectrum, without bands or lines, but in which the various component rays can be readily distinguished. That of *Pyrophorus noctilucus*, for example, is quite remarkable when the animal is very luminous; somewhat extended on the side of the red, it reaches as far as the first blue rays and covers about twenty-four divisions of the micrometer. Its approximate limits are on one side the line B, on the other the line F, of the solar spectrum. So the middle part of that spectrum corresponds to the maximum luminous intensity of the spectrum of *Pyrophorus*.

It should also be noted that the impression produced on the eye warns us that the composition of this light is not the same as that from artificial sources. It is easy to assure ourselves that this is the case by arranging an artificial diaphragm so as to give to a beam of artificial light a photometric intensity approximately equal to that of the luminous organ and then comparing its dispersion with that of the rays from *Pyrophorus*. The graphic representation of the results obtained by this spectroscopic experiment may serve to give an idea of the respective composition of the light of these various sources, but this method is evidently extremely imperfect, since we can not by ordinary photometric processes compare the intensity of lights of different composition.

A *spectro-photometric* analysis, however, taking the wave-lengths for abscissæ and the intensities of the luminous rays for ordinates, shows that the area between the axis of the wave-length and the curve is, in the light from *Pyrophorus*, almost wholly occupied by green and yellow rays (fig. 1). The maximum of intensity corresponds to a wave-length μ 0.528,56. Now, this wave-length is precisely the same as that which affords the maximum of clearness in the solar spectrum, while in the flame of a candle the maximum of luminous intensity corresponds to

the wave-length μ 0.485,68, and is consequently thrown back on the side of the more refrangible rays. An inverse result would have been obtained if the peculiar appearance of the spectrum of *Pyrophorus* was due only to its relatively feeble intensity, since in that case the blue rays would seem more abundant. Finally, in the case of the candle, the yellow rays fall in a narrower part of the area between the curve of intensity and the line of wave-lengths.

In comparing these areas with each other, we find that the spectro-photometric value of one of the two prothoracic lanterns of a *Pyrophorus* would be about one one hundred and fiftieth of a Phœnix candle (8 to the pound). If we admit that the ventral apparatus possesses an illuminating power double that of the prothoracic ones, we see that it would take from thirty-seven to thirty-eight *Pyrophori*, all luminous at once with their three apparatuses, to illuminate an apartment with the same intensity as a candle.

The average wave-length of this light, obtained either by calculation or graphically, is found to be between μ 0.530 and μ 0.533, nearly that of the green line of thallium μ 0.535; and, indeed, the light of *Pyrophorus* is very similar to that of the sun shining through foliage (θαλλός, a green branch).

It should be added that this spectrum is not at all like that of phosphorus burning in oxygen or hydrogen, and hence we can at once reject certain hypotheses relative to the special mechanism of the photogenic function. The green color of the light of *Pyrophorus* is increased by the existence of green matter in the blood, which bathes abundantly the photogenic organs during their action. But besides its special coloration, it possesses a peculiar opalescent luster, on account of which all observers speak of it as of beautiful clarity.

This clarity recalls that of fluorescent substances, and it is this that led us to discover in the blood of *Pyrophorus* a material that becomes luminous when exposed to the influence of the ultra violet rays, especially those having a wave-length of μ 0.391. Dilute acetic acid annuls this fluorescent power, while ammonia restores it. Now, both these reactions affect similarly the photogenic power of all substances, animal or vegetable, and this has led us to think that the production of physiological light was due to the transformation of obscure vibrations, depending on protoplasmic molecular movement, into luminous undulations. But this substance not having been found in the luminous creatures, there is reason to believe that its function is limited to transforming into luminous rays and throwing toward the middle portion of the spectrum the chemical rays that originate simultaneously with the luminous rays in *Pyrophorus*. Thus reenforced, the middle portion of the spectrum forms what might be called a focus of condensed light. I have given to the transforming substance whose composition is unknown, but whose existence can not be doubted, the name of *pyrophorine*.

An organoleptic examination shows, like the physical analysis, that the light of *Pyrophorus* is undoubtedly superior to that of any artificial sources of light with which we are acquainted.

The visual intensity, measured by means of a typographic scale, has been found, when compared with that of a candle, to be much greater than is indicated by the luminous intensity, as determined by the spectrophotometer. The beautiful clarity of the *Pyrophorus* does not favor retinal persistence, there are no accidental images, and complementary color images are produced with difficulty. In spite of its greenish hue, it has almost no influence on the color sense, for all tints are easily recognized, except blue and violet, which do not exist in its spectrum, and its rays are perceived at the extreme limits of the visual field.

The light of the *Pyrophori* contains no polarized rays, which proves that the function attributed to the chalky, radio-crystalline layer of the photogenic organs of insects does not exist. On the contrary, it still includes, in spite of the fluorescence of pyrophorine, a sufficient quantity of chemical rays to effect the photographic reproduction of objects, but no less than five minutes' exposure is necessary to produce, with the ventral organ (the most brilliant of the three), a good proof with gelatin-bromide plates that give with solar light an image in a fraction of a second (fig. 2).

The quantity of heat generated by the photogenic organs is infinitesimal. I have, however, been able to show the presence of a few *heat rays* by means of an extremely sensitive thermo-electric pile, so arranged as to avoid all causes of error. It has also been possible to show that this small quantity of heat is nearly double that given out by the dark portion of the tegument at the same time. The existence of these calorific rays has been completely confirmed by the use of the bolometer, an instrument which informs us, as it appears, that the quantity of heat given off during ten minutes, by the most brilliant *Pyrophorus*, is a seven-millionth of a calory.

The most sensitive instruments fail to show any electric phenomena whatever accompanying the production of the light.

The experiments, taken together, fully justify the conclusions which we published in 1886,[1] namely, that in contrast with artificial light in which 98 per cent of the energy is employed otherwise than in producing illuminating rays, physiological light employs effectively 98 per cent of energy, with only 2 per cent of loss. Besides this immense economic superiority there should be mentioned the exceptional qualities (organoleptic or otherwise) which cause the *Pyrophori* themselves to prefer their own beautiful light to any other, it never causing

[1] See Les Elatérides lumineux: Bulletin de la Société zoologique de France, Paris, 1886. The exactitude of the physical results noted in that work has been fully corroborated by the confirmatory researches of MM. Véry and Langley published in 1890 (see Phil. Magaz., XXX, Series V, p. 260); but these scientists were in error when they said that I had not been able to show the existence of calorific rays.

conflagrations and never being extinguished by the winds nor the rain, being, in fact, an ideal illuminant. Neither need it be supposed that these little lanterns which they always carry with them, and which they can use at any moment, cause any great expenditure, for the total loss of weight of twenty *Pyrophori* in three days and three nights during which they had shone for long hours was found by experiment to be 0.063 gram—that is to say, about 0.03 gram per insect, and during that time they had expended much more energy in movement than in light and had consumed no nutriment. Was I not right when I said in the first place that this physiological light ought, by its composition, to serve as a type for the artificial light of the future, and have not the recent applications of zirconium to illumination already partly shown the accuracy of my predictions? Up to 1886, when I published my first researches, nothing was thought of but the perfecting of the illuminating apparatus then in use. I believe that I opened a new and promising field for future progress by showing the inferiority of these means when compared with those of nature and by placing the question upon the ground of producing illumination by a new method.

II.

Everything goes to prove that there is no analogy between the actual mechanism of the photogenic function and our industrial methods, and we are far from the artless explanation of the blast tubes for burning up the protoplasm, but the analysis of the physiological mechanism of the photogenic organs, and even that of the intracellular modifications that accompany luminous emission (discussed in the first part of this article), have not answered the philosophical question, much more important for us than the economic one: Is the production of physiological light reducible to a simple physical or chemical phenomenon?

We know now that the ultimate element of the phenomenon is physical. Let us examine the work of the vital function.

It will be remembered that the photogenic organ of *Lampyra* dried and pulverized still gives out light when the amorphous dust is moistened with a drop of water. This simple experiment, which may be repeated with a multitude of other photogenic organisms, suffices to prove that it is neither in the structure nor in the working of the organ or of the photogenic cell that we must seek for the ultimate cause of the emission of light.

For simplicity, we will first confine ourselves to the consideration of the photogenic matter furnished by *Pholas dactylus*, because that mollusk produces it freely and quite abundantly in the form of a liquid that remains luminous even after being filtered, then containing in suspension only fine protoplasmic granulations that give it a cloudy appearance. These semifluid granulations, which I have called *vacuolides* because of the appearance that they present under the

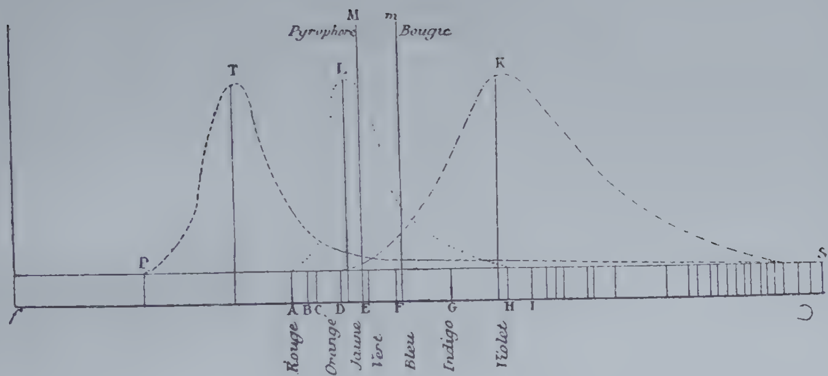
microscope, and which are found in all photogenic elements, must be the plasmatic or microsomic corpuscles of the luminous cells.[1] They are seen to undergo a series of metamorphoses in proportion as their photogenic power becomes exhausted (fig. 3).

Like all protoplasm undergoing catabolic changes—or, to express it otherwise, passing from life to death—these granulations lose, with the energy which they emit, their colloidal nature, passing to the crystalloidal state. But the photogenic protoplasmic matter survives the animal and continues to shine and palpitate for quite a long time after somatic death. It is even possible to retard its spontaneous destruction and to suspend the emission of light by covering the luminous organs with powdered bichromate of soda. There is then formed a peculiar liquor, which becomes luminous upon the addition of water and its agitation in contact with air. Immersion in vinegar produces the same result, and the light may be made to reappear after several days by adding ammonia. But there is no method by which it can be indefinitely preserved. The most advantageous means are those used for preserving pancreatic ferments. The luminous organs sprinkled with very dry, finely powdered carbonate of lime are dried in an oven at 36°. After drying they are separated from the inert powder and macerated in absolute alcohol and ether at 60°. Thus treated, these luminous organs may be relighted by contact with water after a very long, but not an indefinite time. This experiment shows, first, that the photogenic substance is not a fatty matter soluble in alcohol and ether, as has been supposed, and, second, that it is spontaneously destroyed at length, in spite of all precautions against such a result. It thus behaves exactly like certain viruses, such, for example, as vaccine matter. Although absolute alcohol does not destroy it, dilute alcohol does, and, like many microorganisms, it can, when quite dry, resist a temperature of 120°, but in the presence of water its photogenic power is destroyed at 60°.

In order to clearly show that the cell and the photogenic matter are independent, the organs prepared as I have just indicated should be triturated and the luminous liquid thus produced filtered; with this liquid a certain number of reactions may be obtained which I will succinctly state.

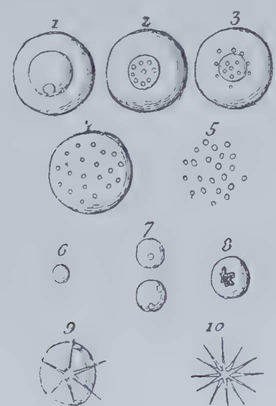
Solutions of *acids* or of *energetic bases* when sufficiently concentrated destroy the luminosity immediately, so that it does not reappear upon neutralizing the liquid. A great number of *neutral* chemical compounds, such as the chlorides of sodium, magnesium, and potassium, sulphates of sodium, magnesium, etc., dissolved in sufficient quantity in the liquid, suspend the emission of light, which, however, reappears upon the addition of a sufficient quantity of water. All the reagents which coagulate albuminoid substances, such as tannin, bichloride of

[1] See Anatomie et physiologie de la Pholade dactyle: Annales de l'Université de Lyon, II, fasc. 2, 1892. Published by Masson, Paris.



10.—Curves of thermic, luminous, and chemical intensities in the solar spectrum.
T, curve of thermic rays; K, curve of chemical rays; L, curve of chemical rays; L, curve of luminous rays; M, position of the spectrophotometric maximum of the light of *Pyrophorus; m*, position of the spectrophotometric maximum of the flame of a candle.

11.—Proof obtained by exposing for five minutes a photographic plate covered with paper lace to the light of a photogenic organ of the *Pyrophorus*.



12.—Photogenic elements:
1, photogenic cell, 2, granular separation in the nucleus; 3 and 4 photogenic granulations floating in the liquefied contents of the cell; 5 granulations set at liberty by the destruction of the cell wall; 6, photogenic granulation; 7, vacuolized condition of the granulation; 8, 9, 10, passage of the granulation to the radio-crystalline condition.

mercury, etc., immediately suppress the luminosity, which fails to reappear when water is added.

The *antiseptics*, phenol and thymol, and many other antiseptic and antizymotic substances extinguish physiological light. *Reducing agents*, such as the sulphydrates, sulphites, and hydrogen, suspend the photogenic property. It is also extinguished by the action of a *vacuum* or by shaking the photogenic liquor with animal charcoal; the light reappears on agitation with air. *Oxidizing reagents*, such as ozone, oxygenated water, and pure oxygen, even at a pressure of several atmospheres, do not increase the intensity of the luminous phenomenon; on the contrary, the action of energetic oxidizing reagents at once and finally extinguishes the light without first causing any increase in its luster.

Cold—that is to say, a temperature of $-15°$ C.—does not finally destroy the photogenic power. The light which disappeared on the freezing of the liquid reappears with unabated intensity after melting. *Heat* excites and hastens the appearance of the light, whose intensity increases up to 30°, remains nearly constant from 30° to 55°, then decreases to finally disappear at 60°. *Electricity* acting upon the saline luminous liquor contained in a U tube induces a series of interesting phenomena. The light first grows pale and is soon extinguished at the negative pole. At this instant the positive pole begins to be obscured, and a moment afterwards only the lower part of the U tube shines. When the liquor at the two poles is extinguished and the current is reversed the light reappears in the branch in which the positive pole is placed, but it does not always reappear at the negative pole. There are produced during electrolysis about the electrodes flocculous deposits in which there may be distinguished granulations having the aspect of more or less modified vacuolides. It is easy to show that the liquor ceases to shine at the negative pole because of nascent hydrogen while it is extinguished at the positive pole, in spite of the presence of nascent and ozonized oxygen because the liquid becomes strongly acid.

All these reactions, as well as many others which I pass over, sufficiently prove that we have to deal with a protoplasmic substance whose spontaneous destruction may be retarded, but not completely suspended, and which behaves toward reagents as do ferments, whether figurate or not; as do viruses; in a word, as does living matter reduced to its simplest expression, living, but yet incapable of reproduction while in that condition. This protoplasmic living matter, after it has dissipated in the form of light the energy that animated it, becomes changed to a crude, crystalline substance, and this is death.

The constant coexistence of these colloidal and crystalloidal substances caused me to think that one of them acted upon the other to produce light, but a more profound study showed me that the crystalline substance was only a transformation of the protoplasmic substance, to which I gave the name *luciferase*.

This transformation takes place under the influence of life, water, and a suitable temperature.

A confirmation of the accuracy of this theory, which I consider as final, has been furnished by my recent researches upon luminous myriapods.[1]

The *Orya barbarica* of Algeria, which we have mentioned in the first part of this article, secretes by special hypodermic unicellular glands a luminous liquid free from foreign matter. The microscope readily reveals not only in the glandular protoplasm, but also in the secreted product, the vacuolides or photogenic granulations, which can be seen to become transformed into magnificent crystals during the emission of light. When the phenomenon is completed the preparation is composed wholly of crystals. The photogenic matter rapidly dried (on filter paper, for example) may remain in a colloidal state for a long time and become reillumined by a drop of water when exposed to air. In the particular case of *Orya barbarica*, one could not apply the hypothesis of Radziszewski, that the luminosity is occasioned by a pure and simple oxidation of certain organic substances in an alkaline medium at an ordinary temperature, for the secretion of *Orya* is clearly acid. Besides, all the reactions indicated for *Pholas* are applicable to the luminous secretion of this Algerian myriapod.

III.

From all these observations and experiments, the following conclusions may be drawn:

First. The photogenic phenomenon requires for its accomplishment neither the integrity of the organ nor of the cellular elements; the activity of the cell alone, when it is not independent, assures the activity of the organ. The cell, in its turn, forms the photogenic substance; but that, when once formed, may shine or become extinguished independently of the anatomical element that produced it, according to circumstances affecting its environment.

Second. The environment must be such as to satisfy the conditions indispensable for the production of the phenomena of life; it should contain water, be oxygenated, and have a suitable temperature.

Third. All the causes that suspend or abolish the activity of zymoses or figurate ferments, or, to speak more generally, protoplasmic activity, also suspend or abolish the photogenic function—that is to say, the production of physiological light.

Fourth. It is in passing, by reason of an inevitable ancestral impulsion, from the state of living protoplasmic granulations to the state of crude crystalloid matter that the photogenic substance disengages at one and the same time, under the form of light, the evolutive energy received from its ancestors and the compensatory energy drawn from its environment.

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[1] See Comptes rendus de l'Académie des Sciences, 17 juillet, 1893.

The final result of the photogenic phenomenon is, then, a physico-chemical one—physical as regards the emission of light, chemical as regards the formation of a crystalline substance; but the formation and transformations of the photogenic protoplasmic granulations are the result of a physiological process and are the exclusive domain of biological mechanics.

We may perhaps better comprehend the importance of the solution of the problem of the mechanism of the photogenic function, a solution which we have sought for many years, if we again read the words of Claude Bernard, which are, as might be said, the scientific testament of that illustrious physiologist, since they were those delivered by him at the close of the last lecture which he gave at the Museum, on the "Phenomena of life common to animals and vegetables," some time before his death.

"Arrived at the termination of our studies, we see that they lead us to a very general conclusion, the result of experiment; namely, that between the two schools, one holding that vital phenomena are absolutely distinct from physico-chemical phenomena, the other that they are wholly identical with them, there is place for a third doctrine, that of physical vitalism, which takes account of what there is peculiar in the manifestations of life, and what there is that conforms to the action of general forces; the ultimate element of the phenomenon is physical, the arrangement is vital."[1]

The study of the photogenic function conducts us to physico-vitalism, or, more exactly, to biological dynamics, which is a department, but a special department, of general mechanics.

[1] Leçons sur les phénomènes de la vie, Paris, 1879, p. 524.

OCEANOGRAPHY, BIONOMICS, AND AQUICULTURE.[1]

By William A. Herdman, F. R. S.

This year, for the first time in the history of the British Association, Section D meets without including in the range of its subject-matter the science of botany. Zoology now remains as the sole occupant of Section D—that "Fourth Committee of Sciences," as it was at first called, more than sixty years ago, when our subject was one of that group of biological sciences, the others being botany, physiology, and anatomy. These allied sciences have successively left us. Like a prolific mother, our section has given rise one after another to the now independent sections of anthropology, physiology, and botany. Our subject-matter has been greatly restricted in scope, but it is still very wide—this year, when Section I, devoted to the more special physiology of the medical physiologist, does not meet, perhaps a little wider than it may be in other years, since we are on this occasion credited with the subject "Animal physiology"—surely always an integral part of zoology! It is to be hoped that this section will always retain that general and comparative physiology which is inseparable from the study of animal form and structure. The late Waynflete professor of physiology at Oxford, in his Newcastle address to this section, said "that every appreciable difference in structure corresponds to a difference of function" (Burdon-Sanderson, British Association Report for 1889), and his successor, the present Waynflete professor, has shown us "how pointless is structure apart from function, and how baseless and unstable is function apart from structure" (Gotch, "Presidential address to Liverpool Biological Society," Vol. IX, 1894)—the "argument for the simultaneous examination of both" in that science of zoology which we profess is, to my mind, irresistible.

We include also in our subject-matter, besides the adult structure and the embryonic development of animals, their distribution both in space and time, the history and structure of extinct forms, speciography and classification, the study of the habits of animals and all that mass

[1]Opening address at the Ipswich meeting of the British Association for the Advancement of Science, 1895. By William A. Herdman, D. Sc., F. R. S., F. L. S., F. R. S. E., professor of natural history in University College. Printed in Report of the British Association, 1895, and in Nature, No. 1351, vol. 52, September 19, 1895.

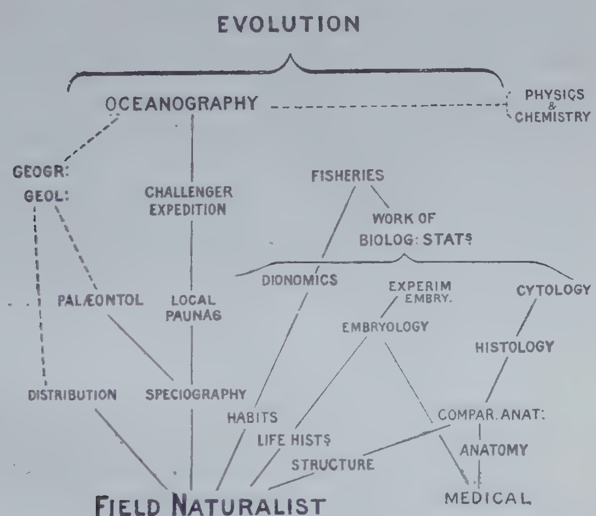
of lore and philosophy which has gathered around inquiries into instinct, breeding, and heredity. I trust that the discussion of matters connected with evolution will always, to a large extent, remain with this Section D, which has witnessed in the past the addresses, papers, discussions, and triumphs of Darwin, Huxley, and Wallace.

When the British Association last met in Ipswich, in 1851, Section D, under the presidency of Professor Henslow, still included zoology, botany, and physiology, and a glance through the volumes of reports for that and neighboring years recalls to us that our subject has undergone great and striking developments in the forty-four years that have elapsed. Zoology was still pre-Darwinian (though Charles Darwin was then in the thick of his epoch-making work—both what he calls his "plain barnacle work" and his "theoretic species work"). (See Life and Letters, Vol. I, p. 380.) Although the cell theory had been launched a decade before, zoologists were not yet greatly concerned with those minute structural details which have since built up the science of histology. The heroes of our science were then chiefly those glorious field naturalists, observers, and systematists who founded and established on a firm basis British marine zoology. Edward Forbes, Joshua Alder, Albany Hancock, were then in active work. George Johnston was at his zoophytes, Bowerbank at sponges, Busk at polyzoa. Forbes's short, brilliant career was nearly run. He probably did more than any of his contemporaries to advance marine zoology. In the previous year, at the Edinburgh meeting of the association, he and his friend MacAndrew had read their classic reports (British Association Report for 1850, p. 192 et seq.) "On the investigation of British marine zoology by means of the dredge," and "On south European marine invertebrata," which mark the high-water level reached at that date, and for some time afterwards, in the exploration of our coasts and the explanation of the distribution of our marine animals. At the Belfast meeting, which followed Ipswich, Forbes exhibited his great map of the distribution of marine life in "Homoiozoic belts." In November, 1854, he was dead, six months after his appointment to the goal of his ambition, the professorship at Edinburgh, where, had he lived, there can be no doubt he would, with his brilliant ability and unique personality, have founded a great school of marine zoology.

To return to the early fifties, Huxley—whose recent loss to science, to philosophy, to culture, we, in common with the civilized world, now deplore—at that time just returned from the memorable voyage of the *Rattlesnake*, was opening out his newly acquired treasures of comparative anatomy with papers on Siphonophora and on Sagitta, and one on the structure of Ascidians, in which he urged—fourteen years before Kowalevsky established it on embryological evidence in 1866—that their relations were with Amphioxus, as we now believe, rather than with the Polyzoa or the Lamellibranchiata, as had formerly been supposed. Bates was then on the Amazons, Wallace was just going out

to the Malay Archipelago, Wyville Thomson, Hincks, and Carpenter, the successors of Forbes, Johnston, and Alder, were beginning their life work. Abroad that great teacher and investigator, Johannes Müller, was training among his pupils the most eminent zoologists, anatomists, and physiologists of the succeeding quarter century. In this country, as we have seen, Huxley was just beginning to publish that splendid series of researches into the structure of nearly all groups in the animal kingdom to which comparative anatomy owes so much.

In fact, the few years before and after the last Ipswich meeting witnessed the activity of some of the greatest of our British zoologists—the time was pregnant with work which has since advanced, and in some respects revolutionized our subject. It was then still usual for the naturalist to have a competent knowledge of the whole range of the natural sciences. Edward Forbes, for example, was a botanist and a



geologist, as well as a zoologist. He occupied the chair of botany at King's College, London, and the presidential chair of the geological section of the British Association at Liverpool in 1854. That excessive specialization, from which most of us suffer in the present day, had not yet arisen; and in the comprehensive, but perhaps not very detailed survey of his subject taken by one of the field naturalists of that time, we find the beginnings of different lines of work, which have since developed into some half dozen distinct departments of zoology, are now often studied independently, and are in some real danger of losing touch with one another. (See diagram.)

The splendid anatomical and "morphological" researches of Huxley and Johannes Müller have been continued by the more minute histological or cellular work rendered possible by improvements of the microtome and the microscope, until at last in these latter years we

investigate not merely the cellular anatomy of the body, but the anatomy of the cell—if, indeed, we are permitted to talk of "cell" at all, and are not rather constrained to express our results in terms of "cytomicrosomes," "somacules," or "idiosomes," and to regard our morphological unit, the cell, as a symbiotic community containing two colonies of totally dissimilar organisms. (See Watasé in "Wood's Holl Biological Lectures," 1893.) To such cytological investigations may well be applied Lord Macaulay's aphorism, "A point which yesterday was invisible is its goal to-day, and will be its starting point to-morrow."

Somewhat similar advances in methods have led us from the life histories studied of old to the new and fascinating science of embryology. The elder Milne-Edwards and Van Beneden knew that in their life histories Ascidians produced tadpole-like young. Kowalevsky (1866) showed that in their embryonic stages these Ascidian tadpoles have the beginnings of their chief systems of organs formed in essentially the same manner and from the same embryonic layers as in the case of the frog's tadpole or any other typical young vertebrate; and now we are not content with less than tracing what is called the "cell-lineage" of such Ascidian embryos, so as to show the ancestry and descendants, the traditions, peculiarities of, and influences at work upon each of the embryonic cells—or areas of protoplasm—throughout many complicated stages. And there is now opening up from this a great new field of experimental and "mechanical" embryology, in which we seek the clew to the explanation of particular processes and changes by determining under what conditions they take place, and how they are affected by altered conditions. We are brought face to face with such curious problems as, Why does a frog's egg, in the two-celled stage, of which one-half has been destroyed, develop into half an embryo when it is kept with one (the black) surface uppermost, and into—not half an embryo, but—a whole embryo of half the usual size if kept with the other (the white) surface upward. Apparently, according to the conditions of the experiment, we may get half embryos or whole embryos of half size from one of the first two cells of the frog's egg.[1]

One of the most characteristic studies of the older field naturalists, the observation of habits, has now become, under the influence of Darwinism, the "Bionomics" of the present day, the study of the relations between habit and structure and environment—a most fascinating and promising field of investigation, which may be confidently expected to tell us much in the future in regard to the competition between species, and the useful or indifferent nature of specific characters.

Other distinct lines of zoological investigation, upon which I shall not dwell, are geographical distribution and paleontology—subjects in which the zoologist comes into contact with and may be of some service to his fellow-workers in geology. And there still remains the

[1] See Morgan, "Anat. Anzeig.," 1895, X, Bd. p. 623, and recent papers by Roux, Hertwig, Born, and O. Schultze.

central avenue of the wide zoological domain—that of speciography and systematic zoology—which has been cultivated by the great classifiers and monographers from Linnæus to Hæckel, and has culminated in our times in the magnificent series of fifty quarto volumes, setting forth the scientific results of the *Challenger* expedition; a voyage of discovery comparable only in its important and wide-reaching results with the voyages of Columbus, Gama, and Magellan at the end of the fifteenth century. It is now so long since the *Challenger* investigations commenced that few, I suppose, outside the range of professional zoologists are aware that although the expedition took place in 1872 to 1876, the work resulting therefrom has been going on actively until now—for nearly a quarter of a century in all—and in a sense, and a very real one, will never cease, for the *Challenger* has left an indelible mark upon science, and will remain through the ages exercising its powerful, guiding influence, like the work of Aristotle, Newton, and Darwin.

Most of the authors of the special memoirs on the sea and its various kinds of inhabitants have interpreted in a liberal spirit the instruction they received to examine and describe the collections intrusted to them, and have given us very valuable summaries of the condition of our knowledge of the animals in question, while some of the reports are little less than complete monographs of the groups. I desire to pay a tribute of respect to my former teacher and scientific chief, Sir Wyville Thomson, to whose initiative, along with Dr. W. B. Carpenter, we owe the first inception of our now celebrated deep-sea dredging expeditions, and to whose scientific enthusiasm, combined with administrative skill, is due in great part the successful accomplishment of the *Lightning*, the *Porcupine*, and the *Challenger* expeditions. Wyville Thomson lived long enough to superintend the first examination of the collections brought home, their division into groups, and the allotment of these to specialists for description. He enlisted the services of his many scientific friends at home and abroad, he arranged the general plan of the work, decided upon the form of publication, and died in 1882, after seeing the first ten or twelve zoological reports through the press.

Within the last few months have been issued the two concluding volumes of this noble series, dealing with a summary of the results, conceived and written in a masterly manner by the eminent editor of the reports, Dr. John Murray. An event of such first-rate importance in zoology as the completion of this great work ought not to pass unnoticed at this zoological gathering. I desire to express my appreciation and admiration of Dr. Murray's work, and I do not doubt that the section will permit me to convey to Dr. Murray the congratulations of the zoologists present, and their thanks for his splendid services to science. Murray, in these "Summary" volumes, has given definiteness of scope and purpose and a tremendous impulse to that branch of science—mainly zoological—which is coming to be called

OCEANOGRAPHY.

Oceanography is the meeting ground of most of the sciences. It deals with botany and zoology, "including animal physiology;" chemistry, physics, mechanics, meteorology, and geology all contribute, and the subject is of course intimately connected with geography, and has an incalculable influence upon mankind, his distribution, characteristics, commerce, and economics. Thus oceanography, one of the latest developments of marine zoology, extends into the domain of, and ought to find a place in, every one of the sections of the British Association.

Along with the intense specialization of certain lines of zoology in the last quarter of the nineteenth century, it is important to notice that there are also lines of investigation which require an extended knowledge of, or at least make use of the results obtained from, various distinct subjects. One of these is oceanography, another is bionomics, which I have referred to above, a third is the philosophy of zoology, or all those studies which bear upon the theory of evolution, and a fourth is the investigation of practical fishery problems, which is chiefly an application of marine zoology. Of these four subjects—which, while analytic enough in the detailed investigation of any particular problem, are synthetic in drawing together and making use of the various divergent branches of zoology and the neighboring sciences—oceanography, bionomics, and the fisheries investigation are most closely related, and I desire to devote the remainder of this address to the consideration of some points in connection with their present position.

Dr. Murray, in a few only too brief paragraphs at the end of his detailed summary of the results of the *Challenger* expedition, which I have alluded to above, states some of the views, highly suggestive and original, at which he has himself arrived from his unique experience. Some of his conclusions are very valuable contributions to knowledge, which will no doubt be adopted by marine zoologists. Others, I venture to think, are less sound and well founded, and will scarcely stand the test of time and further experience. But for all such statements, or even suggestions, we should be thankful. They do much to stimulate further research; they serve, if they can neither be refuted nor established, as working hypotheses; and even if they have to be eventually abandoned, we should bear in mind what Darwin has said as to the difference in their influence on science between erroneous facts and erroneous theories: "False facts are highly injurious to the progress of science, for they often endure long; but false views, if supported by some evidence, do little harm, for everyone takes a salutary pleasure in proving their falseness; and when this is done, one path toward error is closed, and the road to truth is often at the same time opened." (Darwin: The Descent of Man, second edition, 1882, p. 606).

With all respect for Murray's work, and fully conscious of my own

temerity in venturing to differ from one who has had such an extended experience of the sea and its problems, I am constrained to express my disagreement with some of his conclusions. And I am encouraged to do so by the belief that Murray will rightly feel that the best compliment which zoologists can pay to his work is to give it careful, detailed consideration, and discuss it critically. He will, I am sure, join me in the hope that, whether his views or mine prove the false ones, we may be able, by their discussion, to close a "path toward error," and possibly open "the road to truth."

One of the points upon which Murray lays considerable stress, and to the elaboration of which he devotes a prominent position in his "General observations on the distribution of marine organisms," is the presence of what he has called a "mud-line" around coasts at a depth of about 100 fathoms. It is the point "at which minute particles of organic and detrital matters in the form of mud begin to settle on the bottom of the ocean." He regards it as the great feeding ground, and a place where the fauna is most abundant, and from which there have hived off, so to speak, the successive swarms or migrations which have peopled other regions—the deep waters, the open sea, the shallow waters and the estuaries, fresh waters, and land. Murray thus gives to his mud-line both a present and an historic importance which can scarcely be surpassed in the economy of life on this globe. I take it that the historic and the present importance stand or fall together—that the evidence as to the origin of faunas in the past is derived from their distribution at the present day, and I am inclined to think that Murray's opinion as to the distribution of animals in regard to the mud-line is not entirely in accord with the experience of specialists, and is not based upon reliable statistics. Murray's own statement is (*Challenger* Expedition, Summary, Vol. II, p. 1433): "A depth is reached along the continental shores facing the great oceans immediately below which the conditions become nearly uniform in all parts of the world, and where the fauna likewise presents a great uniformity. This depth is usually not far above nor far below the 100-fathom line, and is marked out by what I have elsewhere designated as the *Mud-line*. - - - Here is situated the great feeding ground in the ocean - - -" and he then goes on (p. 1434) to enumerate the Crustaceans, such as species of *Calanus*, *Euchæta*, *Pasiphæa*, *Crangon*, *Calocaris*, *Pandalus*, *Hippolyte*, many amphipods, isopods, and immense numbers of schizopods, which swarm, with fishes and cephalopods, immediately over this mud deposit. Now, I venture to think that the experience of some of those who have studied the marine zoology of our own coasts does not bear out this statement. In the first place, our experience in the Irish Sea is that mud may be found at almost any depth, but is very varied in its nature and in its source. There may even be mud laid down between tide marks in an estuary where a very considerable current runs. A deposit of mud may be due to the presence of an eddy

or a sheltered corner in which the finer particles suspended in the water are able to sink, or it may be due to the wearing away of a limestone beach, or to quantities of alluvium brought down by a stream from the land, or to the presence of a submerged bed of bowlder clay, or even, in some places, to the sewage and refuse from coast towns. Finally, there is the deep-water mud, a very stiff blue-gray substance which sets, when dried, into a firm clay, and this is, I take it, the mud of which Dr. Murray writes. But in none of these cases, and certainly not in the last mentioned, is there in my experience or in that of several other naturalists I have consulted, any rich fauna associated with the mud. In fact, I would regard mud as supporting a comparatively poor fauna as compared with other shallow-water deposits.

For practical purposes, round our own British coasts, it is still convenient to make use of the zones of depth marked out by Forbes. The first of these is the "Littoral zone," the space between tide marks, characterized by the abundance of seaweeds, belonging to the genera *Lichina*, *Fucus*, *Enteromorpha*, *Polysiphonia*, and others, and by large numbers of individuals belonging to common species of *Balanus*, *Mytilus*, *Littorina*, *Purpura*, and *Patella* amongst animals. The second zone is the "Laminarian," which extends from low-water mark to a depth of a few fathoms, characterized by the abundant growth of large seaweeds, belonging to the genera *Laminaria*, *Alaria*, and *Himanthalia*, and by the presence of the beautiful red seaweeds (Florideæ). There is abundance of vegetable food, and animals of all groups swarm in this zone, the numbers both of species and of individuals being very great. The genera *Helcion*, *Trochus*, and *Lacuna* are characteristic molluscan forms in our seas. Next comes Forbes's "Coralline" zone, badly so named, extending from about 10 to 40 or 50 fathoms or so. Here we are beyond the range of the ordinary seaweeds, but the calcareous, coral-like Nullipores are present in places in such abundance as to make up deposits covering the floor of the sea for miles. Hydroid zoophytes and polyzoa are also abundant, and it is in this zone that we find the shell beds lying off our coasts, produced by great accumulations of species of *Pecten*, *Ostrea*, *Pectunculus*, *Fusus*, and *Buccinum*, and forming rich feeding grounds for many of our larger fishes. All groups of marine animals are pretty well represented in this zone, and *Antedon*, *Ophiothrix*, *Ophioglypha*, *Ebalia*, *Inachus*, and *Eurynome* may be mentioned as characteristic genera. Lastly, there is what may be appropriately called the zone of deep mud (although Forbes did not call it so), extending from some 50 fathoms down to (in our seas) 100 or so. The upper limit of this zone is Murray's mud-line. We come upon it in the deep fjord-like sea lochs on the west of Scotland, and in the Irish Sea to the west of the Isle of Man.

Now, of these four zones, my experience is that the last—that of the deep mud—has by far the poorest fauna both in species and in individuals. The mud has a peculiar fauna and one of great interest

to the zoologist, but it is not a rich fauna. It contains some rare and remarkable animals not found elsewhere, such as *Calocaris macandreæ*, *Panthalis oerstedi*, *Lipobranchius jeffreysi*, *Brissopsis lyrifera*, *Amphiura chiajii*, *Isocardia cor*, and *Sagartia herdmani;* and a few striking novelties have been described from it of late years, but we have no reason to believe that the number of these is great compared with the number of animals obtained from shallower waters.

Dr. Murray not only insists upon the abundance of animals on the mud, and its importance as the great feeding ground and place of origin of life in the ocean, but he also (p. 1432) draws conclusions as to the relative numbers of animals taken by a single haul of the trawl in deep and shallow waters which can scarcely be received, I think, by marine zoologists without a protest. His statement runs (p. 1432): "It is interesting to compare single hauls made in the deep sea and in shallow water with respect to the number of different species obtained. For instance, at station 146 in the Southern Ocean, at a depth of 1,375 fathoms, the 200 specimens captured belonged to 59 genera and 78 species." That was with a 10-foot trawl dragged for at most 2 miles during at most two hours. Murray then goes on to say: "In depths less than 50 fathoms, on the other hand, I can not find in all my experiments any record of such a variety of organisms in any single haul even when using much larger trawls and dragging over much greater distances." He quotes the statistics of the Scottish fishery board's trawlings in the North Sea, with a 25-foot trawl, to show that the average catch is 7.3 species of invertebrata and 8.3 species of fish, the greatest number of both together recorded in one haul being 29 species. Murray's own trawlings in the west of Scotland gave a much greater number of species, sometimes as many as 50, "still not such a great variety of animals as was procured in many instances by the *Challenger's* small trawl in great depths.

Now, in the first place, it is curious that Murray's own table on page 1437, in which he shows that the "terrigenous" deposits lying along the shore lines yield many more animals, both specimens and species, per haul, than do the "pelagic" deposits[1] at greater depths, such as red clays and globigerina oozes, seems directly opposed to the conclusion quoted above. In the second place, I am afraid that Dr. Murray has misunderstood the statistics of the Scottish fishery board when he

[1] One of the earliest of the *Challenger* oceanographic results, the classification of the submarine deposits into "terrigenous" and "pelagic," seems inadequate to represent fully the facts in regard to sea bottoms, so I am proposing elsewhere ("Report of Irish Sea Committee") the following amended classification: (1) Terrigenous (Murray), where the deposit is formed chiefly of mineral particles derived from the waste of the land; (2) Neritic, where the deposit is chiefly of organic origin, and is derived from the shells and other hard parts of the animals and plants living on the bottom; (3) Planktonic (Murray's "pelagic"), where the greater part of the deposit is formed of the remains of free-swimming animals and plants which lived in the sea over the deposit.

quotes them as showing that only 7.3 or so species of invertebrates are brought up, on the average, in the trawl net. I happen to know from Mr. Thomas Scott, F. L. S., the naturalist who has compiled the statistics in question, and also from my own observations when on board the *Garland* on one of her ordinary trawling expeditions, that the invertebrata noted down on the station sheet are merely a few of the more conspicuous or in other ways noteworthy animals. No attempt is made—nor could possibly be made in the time—by the one naturalist who has to attend to tow nets, water bottle, the kinds, condition, food, etc., of the fish caught and other matters—to give anything like a complete or even approximate list of the species, still less the number of individuals, brought up in the trawl. I submit, therefore, that it is entirely misleading to compare those Scottish fishery board statistics, which were not meant for such a purpose, but only to give a rough idea of the fauna associated with the fish upon certain grounds, with the carefully elaborated results worked out at leisure by many specialists in their laboratories, of a haul of the *Challenger's* trawl. Of Dr. Murray's own trawlings in the west of Scotland, I can not, of course, speak so positively; but I shall be surprised to learn that the results of each haul were as carefully preserved and as fully worked out by specialists as were the *Challenger* collections.

Lastly, on the next Liverpool marine biology committee's dredging expedition in the Irish Sea after the appearance of Dr. Murray's volumes, I set myself to determine the species taken in a haul of the trawl for comparison with the *Challenger* numbers. The haul was taken on June 23, at 7 miles west from Peel, on the north bank, bottom sand and shells, depth 21 fathoms, with a trawl of only 4-foot beam, less than half the size of the *Challenger* one, and it was not down for more than twenty minutes. I noted down the species observed, and I filled two bottles with undetermined stuff, which my assistant, Mr. Andrew Scott, and I examined the following day in the laboratory. Our list comes to at least 112 species, belonging to at least 103 genera.[1] I counted 120 duplicate specimens, which, added to 112, gives 232 individuals, but there may well have been 100 more. This experience, then, is very different from Murray's, and gives far larger numbers in every respect—specimens, species, and genera—than even the *Challenger* deep-water haul quoted. I append my list of species,[2] and practiced marine zoologists will, I think, see at a glance that it is nothing out of the way; that it is a fairly ordinary assemblage of not uncommon animals, such as is frequently met with when dredging in the Coralline zone. I am

[1] It is interesting, in connection with Darwin's opinion that an animal's most formidable competitors in the struggle for existence are those of its own kind or closely allied forms, to notice the large proportion of genera to species in such hauls. I have noticed this in many lists, and it certainly suggests that closely related forms are comparatively rarely taken together.

[2] See Appendix, page 454.

sure that I have taken better netfuls than this both in the Irish Sea and on the west of Scotland.

In order to get another case on different ground, not of my own choosing, on the first occasion after the publication of Dr. Murray's volumes, when I was out witnessing the trawling observations of the Lancashire sea fisheries steamer *John Fell*, I counted, with the help of my assistant, Mr. Andrew Scott, and the men on board, the results of the first haul of the shrimp trawl. It was taken at the mouth of the Mersey estuary, inside the Liverpool Bar, on what the naturalist would consider very unfavorable ground, with a bottom of muddy sand, at a depth of 6 fathoms. The shrimp trawl ($1\frac{1}{2}$-inch mesh) was down for one hour, and it brought up over 17,000 specimens, referable to at least 39 species,[1] belonging to 34 genera. These numbers have been exceeded on many other hauls taken in the ordinary course of work by the fisheries steamer in Liverpool Bay—for example, on this occasion the fish numbered 5,943; and I have records of hauls on which the fish numbered over 20,000, and the total catch of individual animals must have been nearly 50,000. Can any of Dr. Murray's hauls on the deep mud beat these figures?

The conclusion, then, at which I arrive in regard to the distribution of animals in deep water and in water shallower than 50 fathoms, from my own experience and an examination of the *Challenger* results, is in some respects the reverse of Murray's. I consider that there are more species and more individuals in the shallower waters, that the deep mud as dredged has a poor fauna, that the Coralline zone has a much richer one, and that the Laminarian zone, where there is vegetable as well as animal food, has probably the richest of all.

In order to come to as correct a conclusion as possible on the matter, I have consulted several other naturalists in regard to the smaller groups of more or less free swimming Crustacea, such as Copepoda and Ostracoda, which I thought might possibly be in considerable numbers over the mud. I have asked three well-known specialists on such Cretaceans, viz, Prof. G. S. Brady, F. R. S., Mr. Thomas Scott, F. L. S., and Mr. I. C. Thompson, F. L. S., and they all agree in stating that, although interesting and peculiar, the Copepoda and Ostracoda from

[1] *Solea vulgaris*
Pleuronectes platessa
limanda
Gadus morrhua
æglefinus
merlangus
Clupea spratta
harengus
Trachinus vipera
Agonus cataphractus
Gobius minutus
Raia clavata
maculata
Mytilus edulis
Tellina tenuis
Mactra stultorum
Fusus antiquus
Carcinus mænas
Portunus, sp.
Eupagurus bernhardus
Crangon vulgaris
Sacculina, sp.
Some Amphipoda
Longipedia coronata
Ectinosoma spinipes
Sunaristes paguri
Dactylopus rostratus
Cletodes limicola
Caligus, sp.
Flustra foliacea
Aphrodite aculeata
Pectinaria belgica
Nereis, sp.
Asterias rubens
Hydractinia echinata
Sertularia abietina
Hydrallmania falcata
Aurelia aurita
Cyanæa, sp.

the deep mud are not abundant either in species or in individuals. In answer to the question which of the three regions (1) the Littoral zone, (2) from low water to 20 fathoms, and (3) from 20 fathoms onward, is richest in small, free-swimming, but bottom-haunting, Crustacea, they all replied the middle region from 0 to 20 fathoms, which is the Laminarian zone and the upper edge of the Coralline. Professor Brady assures me that nearly every other kind of bottom and locality is better than mud for obtaining Ostracoda. Mr. T. Scott considers that Ostracoda are most abundant in shallow water, from 5 to 20 fathoms. He tells me that as the result of his experience in Loch Fyne, where a great part of the loch is deep, the richest fauna is always where banks occur, coming up to about 20 fathoms, and having the bottom formed of sand, gravel, and shells. The fauna on and over such banks, which are in the Coralline zone, is much richer than on the deeper mud around them. On an ordinary shelving shore on the west coast of Scotland, Mr. Scott, who has had great experience in collecting, considers that the richest fauna is usually at about 20 fathoms. My own experience in dredging in Norway is the same. In the center of the fjords in deep water, on the mud, there are rare forms, but very few of them, while in shallower water at the sides, above the mud, on gravel, shells, rock, and other bottoms, there is a very abundant fauna.

Probably no group of animals in the sea is of so much importance from the point of view of food as the Copepoda. They form a great part of the food of whales, and of herrings and many other useful fish, both in the adult and in the larval state, as well as of innumerable other animals, large and small. Consequently, I have inquired somewhat carefully into their distribution in the sea, with the assistance of Professor Brady, Mr. Scott, and Mr. Thompson. These experienced collectors all agree that Copepoda are most abundant, both as to species and individuals, close round the shore, amongst seaweeds, or in shallow water in the Laminarian zone over a weedy bottom. Individuals are sometimes extremely abundant on the surface of the sea amongst the plankton, or in shore pools near high water, where, amongst *Enteromorpha*, they swarm in immense profusion; but for a gathering rich in individuals, species, and genera, the experienced collector goes to the shallow waters of the Laminarian zone. In regard to the remaining, higher groups of the Crustacea, my friend Mr. Alfred O. Walker tells me that he considers them most abundant at depths of from 0 to 20 fathoms.

I hope no one will think that these are detailed matters interesting only to the collector, and having no particular bearing upon the great problems of biology. The sea is admittedly the starting point of life on this earth, and the conclusions we come to as to the distribution of life in the different zones must form and modify our views as to the origin of the faunas—as to the peopling of the deep sea, the shallow waters, and the land. Murray supposes that life started in Pre-Cambrian

times on the mud, and from there spread upward into shallower waters, outward on to the surface, and, a good deal later, downward to the abysses by means of the cold Polar waters. The late Professor Moseley considered the pelagic, or surface life of the ocean, to be the primitive life from which all the others have been derived. Prof. W. K. Brooks (The Genus Salpa, 1893, p. 156, etc.) considers that there was a primitive pelagic fauna, consisting of the simplest microscopic plants and animals, and "that pelagic life was abundant for a long period during which the bottom was uninhabited."

I, on the other hand, for the reasons given fully above, consider that the Laminarian zone close to low-water mark is at present the richest in life, that it probably has been so in the past, and that if one has to express a more definite opinion as to where, in Pre-Cambrian times, life in its simplest forms first appeared, I see no reason why any other zone should be considered as having a better claim than what is now the Laminarian to this distinction. It is there, at present, at any rate, in the upper edge of the Laminarian zone, at the point of junction of sea, land, and air. where there is a profusion of food, where the materials brought down by streams or worn away from the land are first deposited, where the animals are able to receive the greatest amount of light and heat, oxygen and food, without being exposed periodically to the air, rain, frost, sun, and other adverse conditions of the Littoral zone. It is there that life—it seems to me—is most abundant, growth most active, competition most severe. It is there, probably, that the surrounding conditions are most favorable to animal life; and, therefore, it seems likely that it is from this region that, as the result of overcrowding, migrations have taken place downward to the abysses, outward on the surface, and upward on to the shore. Finally, it is in this Laminarian zone, probably, that under the stress of competition between individuals and between allied species evolution of new forms by means of natural selection has been most active. Here, at any rate, we find, along with some of the most primitive of animals, some of the most remarkably modified forms, and some of the most curious cases of minute adaptation to environment. This brings us to the subject of

BIONOMICS,

which deals with the habits and variations of animals, their modifications, and the relations of these modifications to the surrounding conditions of existence.

It is remarkable that the great impetus given by Darwin's work to biological investigation has been chiefly directed to problems of structure and development, and not so much to bionomics until lately. Variations amongst animals in a state of nature is, however, at last beginning to receive the attention it deserves. Bateson has collected together, and classified in a most useful book of reference, the numerous scattered observations on variation made by many investigators,

and has drawn from some of these cases a conclusion in regard to the discontinuity of variation which many field zoologists find it hard to accept.

Weldon and Karl Pearson have recently applied the methods of statistics and mathematics to the study of individual variation. This method of investigation, in Professor Weldon's hands, may be expected to yield results of great interest in regard to the influence of variations in the young animal upon the chance of survival, and so upon the adult characteristics of the species. But while acknowledging the value of these methods, and admiring the skill and care with which they have been devised and applied, I must emphatically protest against the idea which has been suggested, that only by such mathematical and statistical methods of study can we successfully determine the influence of the environment on species, gauge the utility of specific characters, and throw further light upon the origin of species. For my part, I believe we shall gain a truer insight into those mysteries which still involve variations and species by a study of the characteristic features of individuals, varieties, and species in a living state in relation to their environment and habits. The mode of work of the old field naturalists, supplemented by the apparatus and methods of the modern laboratory, is, I believe, not only one of the most fascinating, but also one of the most profitable fields of investigation for the philosophical zoologist. Such studies must be made in that modern outcome of the growing needs of our science, the Zoological Station, where marine animals can be kept in captivity under natural conditions, so that their habits may be closely observed, and where we can follow out the old precept—first, observation and reflection; then experiment.

The biological stations of the present day represent, then, a happy union of the field work of the older naturalists with the laboratory work of the comparative anatomist, histologist, and embryologist. They are the culmination of the "Aquarium" studies of Kingsley and Gosse, and of the feeling in both scientific men and amateurs, which was expressed by Herbert Spencer when he said: "Whoever at the seaside has not had a microscope and an aquarium has yet to learn what the highest pleasures of the seaside are." Moreover, I feel that the biological station has come to the rescue, at a critical moment, of our laboratory worker who, without its healthy, refreshing influence, is often in these latter days in peril of losing his intellectual life in the weary maze of microtome methods and transcendental cytology. The old Greek myth of the Libyan giant, Antaeus, who wrestled with Hercules and regained his strength each time he touched his mother earth, is true at least of the zoologist. I am sure he derives fresh vigor from every direct contact with living nature.

In our tanks and artificial pools we can reproduce the Littoral and the Laminarian zones; we can see the methods of feeding and breeding—

the two most powerful factors in influencing an animal. We can study mimicry, and test theories of protective and warning coloration.

The explanations given by these theories of the varied forms and colors of animals were first applied by such leaders in our science as Bates, Wallace, and Darwin, chiefly to insects and birds, but have lately been extended, by the investigations of Giard, Garstang, Clubb, and others, to the case of marine animals. I may mention very briefly one or two examples. Amongst the Nudibranchiate Mollusca—familiar animals around most parts of our British coasts—we meet with various forms which are edible, and, so far as we know, unprotected by any defensive or offensive apparatus. Such forms are usually shaped or colored so as to resemble more or less their surroundings, and so become inconspicuous in their natural haunts. *Dendronotus arborescens*, one of the largest and most handsome of our British Nudibranchs, is such a case. The large, branched processes on its back, and its rich purple brown and yellow markings, tone in so well with the masses of brown and yellow zoophytes and purplish red seaweeds, amongst which we usually find *Dendronotus*, that it becomes very completely protected from observation; and, as I know from my own experience, the practiced eye of the naturalist may fail to detect it lying before him in the tangled forests of a shore pool.

Other Nudibranchs, however, belonging to the genus *Eolis*, for example, are colored in such a brilliant and seemingly crude manner that they do not tone in with any natural surroundings, and so are always conspicuous. They are active in their habits, and seem rather to court observation than to shun it. When we remember that such species of *Eolis* are protected by the numerous stinging cells in the cnidophorous sacs placed on the tips of all the dorsal processes, and that they do not seem to be eaten by other animals, we have at once an explanation of their fearless habits and of their conspicuous appearance. The brilliant colors are in this case of a warning nature, for the purpose of rendering the animal provided with the stinging cells noticeable and recognizable. But it must be remembered that in a museum jar, or in a laboratory dish, or as an illustration in a book or on the wall, *Dendronotus* is quite as conspicuous and striking an animal as *Eolis*. In order to interpret correctly the effect of their forms and colors we must see them alive and at home, and we must experiment upon their edibility or otherwise in the tanks of our biological stations.[1]

Let me give you one more example of a somewhat different kind. The soft, unprotected mollusk, *Lamellaria perspicua*, is not uncommonly found associated (as Giard first pointed out) with colonies of the compound Ascidian *Leptoclinum maculatum*, and in these cases the *Lamellaria* is found to be eating the *Leptoclinum*, and lies in a slight cavity which it has excavated in the Ascidian colony, so as to be about

[1] See my experiments on fishes with Nudibranchs, in Trans. Biol. Soc., Liverpool, Vol. IV, p. 150; and Nature for June 26, 1890.

flush with the general surface. The integument of the mollusk is, both in general tint, and also in surface markings, very like the Ascidian colony with its scattered ascidiozooids. This is clearly a good case of protective coloring. Presumably, the *Lamellaria* escapes the observation of its enemies through being mistaken for a part of the *Leptoclinum* colony; and the *Leptoclinum* being crowded like a sponge with minute, sharp-pointed spicules is, I suppose, avoided as inedible by carnivorous animals, which might devour such things as the soft, unprotected mollusk. But the presence of the spicules evidently does not protect the *Leptoclinum* from *Lamellaria*, so that we have, if the above interpretation is correct, the curious result that the *Lamellaria* profits by a protective characteristic of the *Leptoclinum*, for which it has itself no respect, or, to put it another way, the *Leptoclinum* is protected against enemies to some extent for the benefit of the *Lamellaria*, which preys upon its vitals.

It is to my mind no sufficient objection to theories of protective and warning coloration that careful investigation may from time to time reveal cases where a disguise is penetrated, a protection frustrated, an offensive device supposed to confer inedibility apparently ignored. We must bear in mind that the enemies, as well as their prey, are exposed to competition, are subject to natural selection, are undergoing evolution; that the pursuers and the pursued, the eaters and the eaten, have been evolved together, and that it may be of great advantage to be protected from *some* even if not from all enemies. Just as on land, some animals can browse upon thistles whose "nemo me impune lacessit" spines are supposed to confer immunity from attack, so it is quite in accord with our ideas of evolution by means of natural selection to suppose that some marine animals have evolved an indifference to the noxious sponge or to the bristling Ascidian, which are able, by their defensive characteristics, like the thistle, to repel the majority of invaders.

Although we can keep and study the Littoral and Laminarian animals at ease in our zoological stations, it may perhaps be questioned how far we can reproduce in our experimental and observational tanks the conditions of the Coralline and the Deep-mud zones. One might suppose that the pressure—which we have no means as yet for supplying[1]—and which at 30 fathoms amounts to nearly 100 pounds on the square inch, and at 80 fathoms to about 240 pounds, or over 2 hundredweight on the square inch, would be an essential factor in the life conditions of the inhabitants of such depths, and yet we have kept half a dozen specimens of *Calocaris macandreæ*, dredged from 70 to 80 fathoms, alive at the Port Erin Biological Station for several weeks; we

[1] Following up M. Regnard's experiments, some mechanical arrangement whereby water could be kept circulating and aerated under pressure in closed tanks might be devised, and ought to be tried at some zoological station. I learn from the director at the Plymouth Station that some of the animals from deep water, such as Polyzoa, do not expand in their tanks.

have had both the red and the yellow forms of *Sarcodictyon catenata*, dredged from 30 to 40 fathoms, in a healthy condition with the polypes freely expanded for an indefinite period; and Mr. Arnold Watson has kept the Polynoid worm, *Panthalis oerstedi*, from the deep mud at over 50 fathoms, alive, healthy, and building its tube under observation, first for a week at the Port Erin Station, and for many months at Sheffield, in a comparatively small tank with no depth of water. Consequently, it seems clear that with ordinary care almost any marine animals from such depths as are found within the British area may be kept under observation and submitted to experiment in healthy and fairly natural conditions. The biological station, with its tanks, is in fact an arrangement whereby we bring a portion of the sea with its rocks and bottom deposits and seaweeds, with its inhabitants and their associates, their food and their enemies, and place it for continuous study on our laboratory table. It enables us to carry on the bionomical investigations to which we look for information as to the methods and progress of evolution; in it lie centered our hopes of a comparative physiology of the invertebrates—a physiology not wholly medical—and finally to the biological station we confidently look for help in connection with our coast fisheries. This brings me to the last subject which I shall touch upon, a subject closely related both to oceanography and bionomics, and one which depends much for its future advance upon our biological stations—that is the subject of

AQUICULTURE,

or industrial ichthyology, the scientific treatment of fishery investigations, a subject to which Professor McIntosh has first in this country directed the attention of zoologists, and in which he has been guiding us for the last decade by his admirable researches. What chemistry is to the aniline, the alkali, and some other manufactures, marine zoology is to our fishing industries.

Although zoology has never appealed to popular estimation as a directly useful science having industrial applications in the same way that chemistry and physics have done, and consequently has never had its claims as a subject of technical education sufficiently recognized; still, as we in this section are well aware, our subject has many technical applications to the arts and industries. Biological principles dominate medicine and surgery. Bacteriology, brewing, and many allied subjects are based upon the study of microscopic organisms. Economic entomology is making is value felt in agriculture. Along all these and other lines there is a great future opening up before biology, a future of extended usefulness, of popular appreciation, and of value to the nation—and not the least important of these technical applications will, I am convinced, be that of zoology to our fishing industries. When we consider their enormous annual value—about eight millions sterling at first hand to the fisherman, and a great deal more than that

by the time the products reach the British public, when we remember the very large proportion of our population who make their living, directly or indirectly (as boat builders, net makers, etc.), from the fisheries, and the still larger proportion who depend for an important element in their food supply upon these industries; when we think of what we pay other countries—France, Holland, Norway—for oysters, mussels, lobsters, etc., which we could rear in this country if our sea shores and our sea bottom were properly cultivated; and when we remember that fishery cultivation or aquiculture is applied zoology, we can readily realize the enormous value to the nation which this direct application of our science will one day have—perhaps I ought rather to say, we can scarcely realize the extent to which zoology may be made the guiding science of a great national industry.

The flourishing shellfish industries of France, the oyster culture at Arcachon and Marennes, and the mussel culture by bouchots in the Bay of Aiguillon, show what can be done as the result of encouragement and wise assistance from Government, with constant industry on the part of the people, directed by scientific knowledge. In another direction the successful hatching of large numbers (hundreds of millions) of cod and plaice by Captain Dannevig in Norway, and by the Scottish fishery board at Dunbar, opens up possibilities of immense practical value in the way of restocking our exhausted bays and fishing banks, depleted by the overtrawling of the last few decades.

The demand for the produce of our seas is very great, and would probably pay well for an increased supply. Our choicer fish and shellfish are becoming rarer and the market prices are rising. The great majority of our oysters are imported from France, Holland, and America. Even in mussels we are far from being able to meet the demand. In Scotland alone the long-line fishermen use nearly a hundred millions of mussels to bait their hooks every time the lines are set, and they have to import annually many tons of these mussels at a cost of from £3 to £3 10s. a ton.

Whether the wholesale introduction of the French method of mussel culture, by means of bouchots, on to our shores would be a financial success is doubtful. Material and labor are dearer here, and beds, scars, or scalps seem, on the whole, better fitted to our local conditions; but as innumerable young mussels all around our coast perish miserably every year for want of suitable objects to attach to, there can be no reasonable doubt that the judicious erection of simple stakes or plain bouchots would serve a useful purpose, at any rate in the collection of seed, even if the further rearing be carried on by means of the bed system.

All such aquicultural processes require, however, in addition to the scientific knowledge, sufficient capital. They can not be successfully carried out on a small scale. When the zoologist has once shown, as a laboratory experiment in the zoological station, that a particular thing

can be done—that this fish can be hatched or that shellfish reared—under certain conditions which promise to be an industrial success, then the matter should be carried out by the Government[1] or by capitalists on a sufficiently large scale to remove the risk of results being vitiated by temporary accident or local variation in the conditions. It is contrary, however, to our English traditions for Government to help in such a matter, and if our local sea fisheries committees have not the necessary powers nor the available funds, there remains a splendid opportunity for opulent landowners to erect sea-fish hatcheries on the shores of their estates, and for the rich merchants of our great cities to establish aquiculture in their neighboring estuaries, and by so doing instruct the fishing population, resuscitate the declining industries, and cultivate the barren shores—in all reasonable probability to their own ultimate profit.

In addition to the farming of our shores, there is a great deal to be done in promoting the fishing industries on the inshore and offshore grounds along our coast, and in connection with such work the first necessity is a thorough scientific exploration of our British seas by means of a completely fitted dredging and trawling expedition. Such exploration can only be done in little bits, spasmodically, by private enterprise. From the time of Edward Forbes it has been the delight of British marine zoologists to explore, by means of dredging from yachts or hired vessels during their holidays, whatever areas of the neighboring seas were open to them. Some of the greatest names in the roll of our zoologists, and some of the most creditable work in British zoology, will always be associated with dredging expeditions. Forbes, Wyville Thomson, Carpenter, Gwyn Jeffreys, McIntosh, and Norman—one can scarcely think of them without recalling—

"Hurrah for the dredge, with its iron edge,
And its mystical triangle,
And its hided net, with meshes set,
Odd fishes to entangle!"[2]

Much good pioneer work in exploration has been done in the past by these and other naturalists, and much is now being done locally by committees or associations—by the Dublin Royal Society on the west of Ireland, by the Marine Biological Association at Plymouth, by the Fishery Board in Scotland, and by the Liverpool Marine Biology Committee in the Irish Sea; but few zoologists or zoological committees have the means, the opportunity, the time to devote, along with their professional duties, to that detailed, systematic survey of our whole British sea area which is really required. Those who have not had

[1] We require in England a central board or Government department of fisheries, composed in part of scientific experts, and that not merely for the purpose of imposing and enforcing regulations, but still more, in order that research into fisheries problems may be instituted and aquicultural experiments carried out.

[2] The Dredging Song. (See "Memoir of Edward Forbes," p. 247.)

experience of it can scarcely realize how much time, energy, and money it requires to keep up a series of dredging expeditions, how many delays, disappointments, expensive accidents, and real hardships there are, and how often the naturalist is tempted to leave unprofitable grounds, which ought to be carefully worked over, for some more favored spot where he knows he can count upon good spoil. And yet it is very necessary that the whole ground—good or bad though it may be from the zoological point of view—should be thoroughly surveyed, physically and biologically, in order that we may know the conditions of existence which environ our fishes on their feeding grounds, their spawning grounds, their "nurseries," or whatever they may be.

The British Government has done a noble piece of work, which will redound to its everlasting credit, in providing for and carrying out the *Challenger* expedition. Now that that great enterprise is completed, and that the whole scientific world is united in appreciation of the results obtained, it would be a glorious consequence, and surely a very wise action in the interests of the national fisheries, for the Government to fit out an expedition, in charge of two or three zoologists and fisheries experts, to spend a couple of years in exploring more systematically than has yet been done, or can otherwise be done, our British coasts from the Laminarian zone down to the deep mud. No one could be better fitted to organize and direct such an expedition than Dr. John Murray.

Such a detailed survey of the bottom and the surface waters, of their conditions and their contents, at all times of the year for a couple of years, would give us the kind of information we require for the solution of some of the more difficult fishery problems—such as the extent and causes of the wanderings of our fishes, which "nurseries" are supplied by particular spawning grounds, the reason of the sudden disappearance of a fish, such as the haddock, from a locality, and in general the history of our food fishes throughout the year. It is creditable to our Government to have done the pioneer work in exploring the great ocean, but surely it would be at least equally creditable to them—and perhaps more directly and immediately profitable, if they look for some such return from scientific work—to explore our own seas and our own sea fisheries.

There is still another subject connected with the fisheries which the biologist can do much to elucidate—I mean the diseases of edible animals and the effect upon man of the various diseased conditions. It is well known that the consumption of mussels taken from stagnant or impure water is sometimes followed by severe symptoms of irritant poisoning which may result in rapid death. This "musselling" is due to the presence of an organic alkaloid or ptomaine, in the liver of the mollusk, formed doubtless by a microorganism in the impure water. It is clearly of the greatest importance to determine accurately under what conditions the mussel can become infected by the microorganism,

in what stage it is injurious to man, and whether, as is supposed, steeping in pure water with or without the addition of carbonate of soda will render poisonous mussels fit for food.

During this last year there has been an outcry, almost amounting to a scare, and seriously affecting the market,[1] as to the supposed connection between oysters taken from contaminated water and typhoid fever. This, like the musselling, is clearly a case for scientific investigation, and, with my colleague, Professor Boyce, I have commenced a series of experiments and observations, partly at the Port Erin Biological Station, where we have oysters laid down on different parts of the shore under very different conditions, as well as in dishes and tanks, and partly at University College, Liverpool.

Our object is to determine the effect of various conditions of water and bottom upon the life and health of the oyster, the effect of the addition of various impurities to the water, the conditions under which the oyster becomes infected with the typhoid bacillus, and the resulting effect upon the oyster, the period during which the oyster remains infectious, and, lastly, whether any simple practicable measures can be taken (1) to determine whether an oyster is infected with typhoid, and (2) to render such an oyster innocuous to man. As Professor Boyce and I propose to lay a paper upon this subject before the section, I shall not occupy further time now by a statement of our methods and results.

I have probably already sufficiently indicated to you the extent and importance of the applications of our science to practical questions connected with our fishing industries. But if the zoologist has great opportunities for usefulness, he ought always to bear in mind that he has also grave responsibilities in connection with fisheries investigations. Much depends upon the results of his work. Private enterprise, public opinion, local regulations, and even imperial legislation, may all be affected by his decisions. He ought not lightly to come to conclusions upon weighty matters. I am convinced that of all the varied lines of research in modern zoology, none contains problems more interesting and intricate than those of bionomics, oceanography, and the fisheries, and of these three series the problems connected with our fisheries are certainly not the least interesting, not the least intricate, and not the least important in their bearing upon the welfare of mankind.

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[1] I am told that between December and March the oyster trade decreased 75 per cent.

APPENDIX.

List of species taken in one haul, on June 23, 1895 (see p. 442.)

SPONGES:

Reniera, sp.
Halichondria, sp.
Cliona celata
Suberites domuncula
Chalina oculata

COELENTERATA:

Dicoryne conferta
Halecium halecinum
Sertularia abietina
Coppinia arcta
Hydrallmania falcata
Campanularia verticillata
Lafoëa dumosa
Antennularia ramosa
Alcyonium digitatum
Virgularia mirabilis
Sarcodictyon catenata
Sagartia, sp.
Adamsia palliata

ECHINODERMATA:

Cucumaria, sp.
Thyone fusus
Asterias rubens
Solaster papposus
Stichaster roseus
Porania pulvillus
Palmipes placenta
Ophiocoma nigra
Ophiothrix fragilis
Amphiura chiajii
Ophioglypha ciliata
albida
Echinus sphæra
Spatangus purpureus
Echinocardium cordatum
Brissopsis lyrifera
Echinocyamus pusillus

VERMES:

Nemertes neesii

VERMES—Continued.

Chætopterus, sp.
Spirorbis, sp.
Serpula, sp.
Sabella, sp.
Owenia filiformis
Aphrodite aculeata
Polynoë, sp.

CRUSTACEA:

Scalpellum vulgare
Balanus, sp.
Cyclopicera nigripes
Acontiophorus elongatus
Artotrogus magniceps
Dyspontius striatus
Zaus goodsiri
Laophonte thoracica
Stenhelia reflexa
Lichomolgus forficula
Anonyx, sp.
Galathea intermedia
Munida bamffica
Crangon spinosus
Stenorhynchus rostratus
Inachus dorsettensis
Hyas coarctatus
Xantho tuberculatus
Portunus pusillus
Eupagurus bernhardus
prideauxii
cuanensis
Eurynome aspera
Ebalia tuberosa

POLYZOA:

Pedicellina cernua
Tubulipora, sp.
Crisia cornuta
Cellepora pumicosa, and three or four undetermined species of Lepralids

POLYZOA—Continued.

Flustra securifrons
Scrupocellaria reptans
Cellularia fistulosa

MOLLUSCA:

Anomia ephippium
Ostrea edulis
Pecten maximus
opercularis
tigrinus
pusio
Mytilus modiolus
Nucula nucleus
Cardium echinatum
Lissocardium norvegicum
Cyprina islandica
Solen pellucidus
Venus gallina
Lyonsia norvegica
Scrobicularia prismatica
Astarte sulcata
Modiolaria marmorata
Saxicava rugosa
Chiton, sp.
Dentalium entale
Emarginula fissura
Velutina lævigata
Turritella terebra
Natica alderi
Fusus antiquus
Aporrhais pespelicani
Oscanius membranaceus
Doris, sp.
Eolis coronata
Tritonia plebeia

TUNICATA:

Ascidiella virginea
Styelopsis grossularia
Eugyra glutinans
Botryllus, sp.
B., sp.

BOTANICAL WORK OF THE BRITISH ASSOCIATION.[1]

By W. T. Thiselton-Dyer, F. R. S.

The establishment of a new section of the British Association, devoted to botany, can not but be regarded by the botanists of this country as an event of the greatest importance. For it is practically the first time that they have possessed an independent organization of their own. It is true that for some years past we have generally been strong enough to form a separate department of the old Biological Section D, on the platform of which so many of us in the past have acted in some capacity or other, and on which, indeed, many of us may be said to have made our first appearance. We shall not start, then, on our new career without the remembrance of filial affection for our parent, and the earnest hope that our work may be worthy of its great traditions.

The first meeting of the section, or, as it was then called, committee, at Oxford was held in 1832. And though there has been from time to time some difference in the grouping of the several biological sciences, the two great branches of biology have only now for the first time formally severed the partnership into which they entered on that occasion. That this severance, if inevitable from force of circumstances, is in some respects a matter of regret, I do not deny. Specialization is inseparable from scientific progress; but it will defeat its own end in biology if the specialist does not constantly keep in touch with those fundamental principles which are common to all organic nature. We shall have to take care that we do not drift into a position of isolation. Section D undoubtedly afforded a convenient opportunity for discussing many questions on which it was of great advantage that workers in the two different fields should compare their results and views. But I hope that by means of occasional conferences we shall still, in some measure, be able to preserve this advantage.

[1]Opening address by W. T. Thiselton-Dyer, M. A., F. R. S., C. M. G., C. I. E., director of the Royal Gardens, at 1895 meeting of the British Association at Ipswich, printed in Report of the British Association, 1895, and in Nature, No. 1352, vol. 52, September 26, 1895.

RETROSPECT.

I confess I found it a great temptation to review, however imperfectly, the history and fortunes of our subject while it belonged to Section D. But to have done so would have been practically to have written the history of botany in this country since the first third of the century. Yet I can not pass over some few striking events.

I think that the earliest of these must undoubtedly be regarded as the most epoch making. I mean the formal publication by the Linnæan Society, in 1833, of the first description of "the nucleus of the cell," by Robert Brown. (Misc. Bot. Works, I, 512.) It seems difficult to realize that this may be within the recollection of some who are now living amongst us. It is, however, of peculiar interest to me that the first person who actually distinguished this all-important body, and indicated it in a figure, was Francis Bauer, thirty years earlier, in 1802. This remarkable man, whose skill in applying the resources of art to the illustration of plant anatomy has never, I suppose, been surpassed, was "resident draftsman for fifty years to the Royal Botanic Garden at Kew." And it was at Kew, and in a tropical orchid, *Phaius grandifolius*, no doubt grown there, that the discovery was made.

It was, I confess, with no little admiration that, on refreshing my memory by a reference to Robert Brown's paper, I read again the vivid account which he gives in a footnote of the phenomena, so painfully familiar to many of us who have been teachers, exhibited in the staminal hair of *Tradescantia*. Sir Joseph Hooker (Proc. Linn. Soc., 1887–88, 65) has well remarked that "the supreme importance of this observation, - - - leading to undreamt-of conceptions of the fundamental phenomena of organic life, is acknowledged by all investigators."

It is singular that so profound an observer as Robert Brown should have himself missed the significance of what he saw. The world had to wait for the discovery of protoplasm by Von Mohl till 1846, and till 1850 for its identification with the sarcode of zoologists by Cohn, who is still, I am happy to say, living and at work, and to whom last year the Linnæan Society did itself the honor of presenting its medal.

The Edinburgh meeting of the association, in 1834, was the occasion of the announcement of another memorable discovery of Robert Brown's. I will content myself with quoting Hofmeister's (Higher Cryptogamia, 432) account of it: "Robert Brown was the discoverer of the polyembryony of the *Coniferæ*. In a later treatise he pointed out the origin of the pro-embryo in large cells of the endosperm, to which he gave the name of corpuscula." The period of the forties, just half a century ago, looks in the retrospect as one of almost dazzling discovery. To say nothing of the formal appearance of protoplasm on the scene, the foundations were being laid in all directions of our modern botanical morphology. Yet its contemporaries viewed it with a very philosophical

calm. Thwaites, who regarded Carpenter as his master, described at the Oxford meeting in 1847 the conjugation of the *Diatomaceæ*, and "distinctly indicated," as Carpenter (Memorial Sketch, 140) says, "that conjugation is the primitive phase of sexual reproduction." Berkeley informed me that the announcement fell perfectly flat. A year or two later Suminski came to London with his splendid discovery (1848) of the archegonia of the fern, the antheridia having been first seen by Nägeli in 1844. Carpenter (loc. cit., 141) gave me, many years after, a curious account of its reception. "At the council of the Ray Society, at which," he said, "I advocated the reprodnction of Suminski's book on the 'Ferns,' I was assured that the close resemblance of the antherozoids to spermatozoa was quite sufficient proof that they could have nothing to do with vegetable reproduction. I do not think," he added—and the complaint is pathetic—"that the men of the present generation, who have been brought up in the *light*, quite apprehend (in this as in other matters) the utter darkness in which we were then groping, or fully recognize the deserts of those who helped them to what they now enjoy." This was in 1875, and I suppose is not likely to be less true now.

The Oxford meeting in 1860 was the scene of the memorable debate on the origin of species, at which it is interesting to remember that Henslow presided. On that occasion, Section D reached its meridian. The battle was Homeric. However little to the taste of its author, the launching of his great theory was, at any rate, dignified with a not inconsiderable explosion. It may be that it is not given to the men of our day to ruffle the dull level of public placidity with disturbing and far-reaching ideas. But if it were, I doubt whether we have, or need now, the fierce energy which inspired then either the attack or the defense. When we met again in Oxford last year, the champion of the old conflict stood in the place of honor, acclaimed of all men, a beautiful and venerable figure. We did not know then that that was to be his farewell.

The battle was not in vain. Six years afterwards, at Nottingham, Sir Joseph Hooker delivered his classical lecture on Insular Floras. It implicitly accepted the new doctrine, and applied it with admirable effect to a field which had long waited for an illuminating principle. The lecture itself has since remained one of the corner stones of that rational theory of the geographical distribution of plants which may, I think, be claimed fairly as of purely English origin.

HENSLOW.

Addressing you as I do at Ipswich, there is one name written in the annals of our old section which I can not pass over—that of Henslow. He was the secretary of the Biological Section at its first meeting in 1832, and its president at Bristol in 1836. I suppose there are few men of this century who have indirectly more influenced the current of human thought. For in great measure I think it will not be contested

that we owe Darwin to him. As Romanes has told us (Memorial Notices, 13): "His letters written to Professor Henslow during his voyage round the world overflow with feelings of affection, veneration, and obligation to his accomplished master and dearest friend—feelings which throughout his life he retained with no diminished intensity. As he used himself to say, before he knew Professor Henslow, the only objects he cared for were foxes and partridges."

I do not wish to overstate the facts. The possession of "the collector's instinct, strong in Darwin from his childhood, as is usually the case in great naturalists," to use Huxley's (Proc. R. S., XLIV, vi) words, would have borne its usual fruit in after life, in some shape or other, even if Darwin had not fallen into Henslow's hands. But then the particular train of events which culminated in the great work of his life would never have been started. It appeared to me, then, that it would not be an altogether uninteresting investigation to ascertain something about Henslow himself. The result has been to provide me with several texts, which I think it may be not unprofitable to dwell upon on the present occasion.

In the first place, what was the secret of his influence over Darwin? "My dear old master in natural history" (Life, II, 317), he calls him; and to have stood in this relation to Darwin[1] is no small matter. Again, he speaks of his friendship with him as "a circumstance which influenced my whole career more than any other" (I, 52). The singular beauty of Henslow's character, to which Darwin himself bore noble testimony, would count for something, but it would not in itself be a sufficient explanation. Nor was it that intellectual fascination which often binds pupils to the master's feet; for, as Darwin tells us, "I do not suppose that anyone would say that he possessed much original genius" (I, 52). The real attraction seems to me to be found in Henslow's possession, in an extraordinary degree, of what may be called the natural history spirit. This resolves itself into keen observation and a lively interest in the facts observed. "His strongest taste was to draw conclusions from long-continued minute observations" (I, 52). The old natural history method, of which it seems to me that Henslow was so striking an embodiment, is now, and I think unhappily, almost a thing of the past. The modern university student of botany puts his elders to blush by his minute knowledge of some small point in vegetable histology. But he can tell you little of the contents of a country hedgerow, and if you put an unfamiliar plant in his hands he is pretty much at a loss how to set about recognizing its affinities. Disdaining the field of nature spread at his feet in his own country, he either seeks salvation in a German laboratory or hurries off to the tropics, convinced that he will at once immortalize himself. But cœlum non animum mutat; he puts into "pickle" the same objects as his predecessors,

[1] As I shall have frequent occasion to quote the Life and Letters, I shall insert the references in the text.

never to be looked at again; or perhaps writes a paper on some obvious phenomena which he could have studied with less fatigue in the Palm House at Kew.

The secret of the right use of travel is the possession of the natural history instinct, and to those who contemplate it I can only recommend a careful study of Darwin's Naturalist's Voyage. Nothing that came in his way seems to have evaded him or to have seemed too inconsiderable for attention. No doubt some respectable travelers have lost themselves in a maze of observations that have led to nothing. But the example of Darwin, and I might add of Wallace, of Huxley, and of Moseley, show that that result is the fault of the man and not of the method. The right moment comes when the fruitful opportunity arrives to him who can seize it. The first strain of the prelude with which the "Origin" commences are these words: "When on board H. M. S. *Beagle* as naturalist, I was much struck with certain facts in the distribution of the organic beings inhabiting South America." But this sort of vein is not struck at hazard or by him who has not served a tolerably long apprenticeship to the work.

When one reads and rereads the "Voyage," it is simply amazing to see how much could be achieved with a previous training which we now should think ludicrously inadequate. Before Henslow's time the state of the natural sciences at Cambridge was incredible. In fact, Leonard Jenyns (Memoir, 175), his biographer, speaks of the "utter disregard paid to natural history in the university previous to his taking up his residence there." The professor of botany had delivered no lectures for thirty years, and though Sir James Smith, the founder of the Linnæan Society, had offered his services, they were declined on the ground of his being a Nonconformist (ibid., 37).

As to Henslow's own scientific work, I can but rely on the judgment of those who could appreciate it in relation to its time. According to Berkeley (ibid., 56), "he was certainly one of the first, if not the very first, to see that two forms of fruit might exist in the same fungus." And this, as we now know, was a fundamental advance in this branch of morphology. Sir Joseph Hooker tells me that his papers were all distinctly in advance of his day. Before occupying the chair of botany, he held for some years that of mineralogy. Probably he owed this to his paper on the "Isle of Anglesey," published when he was only 26. I learn from the same authority that this to some extent anticipated, but at any rate strongly influenced, Sedgwick's subsequent work in the same region.

BOTANICAL TEACHING.

Henslow's method of teaching deserves study. Darwin says of his lectures "that he liked them much for their extreme clearness." "But," he adds, "I did not study botany" (I, 48). Yet we must not take this too seriously. Darwin (Voyage, 421), when at the Galapagos, "indiscriminately collected everything in flower on the different islands, and

fortunately kept my collections separate." Fortunately indeed: for it was the results extracted from these collections, when worked up subsequently by Sir Joseph Hooker, which determined the main work of his life. "It was such cases as that of the Galapagos Archipelago which chiefly led me to study the origin of species" (III, 159).

Henslow's actual method of teaching went some way to anticipate the practical methods of which we are all so proud. "He was the first to introduce into the botanical examination for degrees in London the system of practical examination" (Memoir, 161). But there was a direct simplicity about his class arrangements characteristic of the man. "A large number of specimens - - - were placed in baskets on a side table in the lecture room, with a number of wooden plates and other requisites for dissecting them after a rough fashion, each student providing himself with what he wanted before taking his seat" (ibid., 39). I do not doubt that the results were, in their way, as efficient as we obtain now in more stately laboratories.

The most interesting feature about his teaching was not, however, its academic aspect, but the use he made of botany as a general educational instrument. "He always held that a man of no powers of observation was quite an exception" (ibid., 163). He thought (and I think he proved) that botany might be used "for strengthening the observant faculties and expanding the reasoning powers of children in all classes of society" (ibid., 99). The difficulty with which those who undertake now to teach our subject have to deal is that most people ask the question, What is the use of learning botany unless one means to be a botanist? It might, indeed, be replied that as the vast majority of people never learn anything effectively, they might as well try botany as anything else. But Henslow looked only to the mental discipline; and it was characteristic of the man and of his belief in his methods that when he was summoned to court to lecture to the royal family, his lectures "were, in all respects, identical with those he was in the habit of giving to his little Hitcham scholars" (Memoir, 149): and it must be added that they were not less successful.

This success naturally attracted attention. Botanical teaching in schools was taken up by the Government, and continues to receive support to the present day. But the primitive spirit has, I am afraid, evaporated. The measurement of results by means of examination has been fatal to its survival. The teacher has to keep steadily before his eyes the necessity of earning his grant. The educational problem retires into the background. "The strengthening of the observant faculties," and the rest of the Henslowian programme, must give way to the imperious necessity of presenting to the examiner candidates equipped with at least the minimum of text-book formulas reproducible on paper. I do not speak in this matter without painful experience. The most astute examiner is defeated by the still more astute crammer. The objective basis of the study on which its whole usefulness is built

up is promptly thrown aside. If you supply the apple blossom for actual description, you are as likely as not to be furnished with a detailed account of a buttercup. The training of observation has gone by the board and the exercise of mere memory has taken its place. But a table of logarithms or a Hebrew grammar would serve this purpose equally well. Yet I do not despair of Henslow's work still bearing fruit. The examination system will collapse from the sheer impossibility of carrying it on beyond a certain point. Freed from its trammels, the teacher will have greater scope for individuality, and the result of his labors will be rewarded after some intelligent system of inspection. And here I may claim support from an unexpected quarter. Mr. Gladstone has recently written to a correspondent: "I think that the neglect of natural history, in all its multitude of branches, was the grossest defect of our old system of training for the young; and, further, that little or nothing has been done by way of remedy for that defect in the attempts made to alter or reform that system." I am sure that the importance and weight of this testimony, coming as it does from one whose training and sympathies have always been literary, can not be denied. That there is already some revival of Henslow's methods, I judge from the fact that I have received applications from board schools, amounting to some hundreds, for surplus specimens from the Kew Museums. Without a special machinery for the purpose I can not do much, and perhaps it is well. But my staff have willingly done what was possible, and from the letters I have received I gather that the labor has not been wholly misspent.

MUSEUM ARRANGEMENT.

This leads me to the last branch of Henslow's scientific work on which I am able to touch, that of the arrangement of museums, especially those which being local have little meaning unless their purpose is strictly educational. I think it is now generally admitted that both in the larger and narrower aspects of the question, his ideas, which were shared in some measure by Edward Forbes, were not merely far in advance of his time, but was essentially sound. And here I can not help remarking that the zoologists have perhaps profited more by his teaching than the botanists. I do not know how far Sir William Flower and Professor Lankester would admit the influence of Henslow's ideas. But so far as my knowledge goes, I am not aware that, at any rate in Europe, there is anything to be seen in public museums comparable to the educational work accomplished by the one at the College of Surgeons and the Natural History Museum, and by the other at Oxford.

I have often thought it singular that in botany we have not kept pace in this matter with our brother naturalists. I do not doubt that vegetable morphology and a vast number of important facts in evolution, as illustrated from the vegetable kingdom, might be presented to

the eye in a fascinating way in a carefully arranged museum. The most successful and, indeed, almost the only attempt which has been made in this direction is that at Cambridge, which, I believe, is due to Mr. Gardiner. But our technical methods for preserving specimens still leave much to desire. Something more satisfactory will, it may be hoped, some day be devised, and the whole subject is one which is well worth the careful consideration of our section. Henslow at least effected a vast improvement in the mode of displaying botanical objects; and a collection prepared by his own hands, which was exhibited at one of the Paris exhibitions, excited the warm admiration of the French botanists, who always appreciate the clear illustration of morphological facts.

OLD SCHOOL OF NATURAL HISTORY.

If the old school of natural history, of which Henslow in his day was a living spirit, is at present, as seems to be the case, continually losing its hold upon us, this has certainly not been due to its want of value as an educational discipline or to its sterility in contributing new ideas to human knowledge. Darwin's Origin of Species may certainly be regarded as its offspring, and of this Huxley (Proc. R. S., XLIV, xvii,) says with justice: "It is doubtful if any single book except the Principia, ever worked so great and rapid a revolution in science or made so deep an impression on the general mind." Yet Darwin's biographer, in that admirable Life which ranks with the few really great biographies in our language, remarks (I, 155): "In reading his books, one is reminded of the older naturalists rather than of the modern school of writers. He was a naturalist in the old sense of the word, that is, a man who works at many branches of science, not merely a specialist in one." This is no doubt true, but does not exactly hit off the distinction between the kind of study which has gone out of fashion and that which has come in. The older workers in biology were occupied mainly with the external or, at any rate, grosser features of organisms and their relation to surrounding conditions; the modern, on the other hand, are engaged on the study of internal and intimate structure. Work in the laboratory, with its necessary limitations, takes the place of research in the field. One may almost, in fact, say that the use of the compound microscope divides the two classes. Asa Gray has compared Robert Brown with Darwin as the "two British naturalists" who have "more than any others, impressed their influence upon science in the nineteenth century" (Nature, X, 80). Now, it is noteworthy that Robert Brown did all his work with a simple microscope. And Francis Darwin writes of his father: "It strikes us nowadays as extraordinary that he should have had no compound microscope when he went his *Beagle* voyage; but in this he followed the advice of Robert Brown, who was an authority on such matters" (I, 145). One often meets with persons, and sometimes of no small eminence, who speak as if there were some

necessary antagonism between the old and the new studies. Thus I have heard a distinguished systematist describe the microscope as a curse, and a no less distinguished morphologist speak of a herbarium having its proper place on a bonfire. To me I confess this anathematization of the instruments of research proper to any branch of our subject is not easily intelligible. Yet in the case of Darwin himself it is certain that if his earlier work may be said to rest solely on the older methods, his later researches take their place with the work of the new school. At our last meeting Pfeffer vindicated one of his latest and most important observations.

The case of Robert Brown is even more striking. He is equally great whether we class him with the older or the modern school. In fact, so far as botany in this country is concerned, he may be regarded as the founder of the latter. It is to him that we owe the establishment of the structure of the ovule and its development into the seed. Even more important were the discoveries to which I have already referred, which ultimately led to the establishment of the group of Gymnosperms. "No more important discovery," says Sachs (History, 142), "was ever made in the domain of comparative morphology and systematic botany. The first steps toward this result, which was clearly brought out by Hofmeister twenty-five years later, were secured by Robert Brown's researches, and he was incidentally led to these researches by some difficulties in the construction of the seed of an Australian genus." Yet it may be remembered that he began his career as naturalist to Flinders's expedition for the exploration of Australia. He returned to England with 4,000 "for the most part new species of plants." And these have formed the foundation of our knowledge of the flora of that continent. Brown's chief work was done between 1820 and 1840, and, as Sachs (loc. cit., 139, 140) tells us, "was better appreciated during that time in Germany than in any other country."

MODERN SCHOOL.

The real founder of the modern teaching in this country in both branches of biology I can not doubt was Carpenter. The first edition of his admirable Principles of Comparative Physiology was published in 1838, the last in 1854. All who owe, as I do, a deep debt of gratitude to that book will agree with Huxley (Memorial Sketch, 67) in regarding it as "by far the best general survey of the whole field of life and of the broad principles of biology which had been produced up to the time of its publication. Indeed," he adds, "although the fourth edition is now in many respects out of date, I do not know its equal for breadth of view, sobriety of speculation, and accuracy of detail."

The charm of a wide and philosophic survey of the different forms under which life presents itself could not but attract the attention of teachers. Rolleston elaborated a course of instruction in zoology at Oxford in which the structures described in the lecture room were

subsequently worked out in the laboratory. In 1872, Huxley organized the memorable course in elementary biology at South Kensington which has since, in its essential features, been adopted throughout the country. In the following year, during Huxley's absence abroad through ill health, I arranged, at his request, a course of instruction on the same lines for the vegetable kingdom.

That the development of the new teaching was inevitable can hardly be doubted, and I for my part am not disposed to regret the share I took in it. But it was not obvious, and certainly it was not expected, that it would to so large an extent cut the ground from under the feet of the old natural history studies. The consequences are rather serious, and I think it is worth while pointing them out.

In a vast empire like our own, there is a good deal of work to be done and a good many posts to be filled, for which the old natural history training was not merely a useful, but even a necessary preparation. But at the present time the universities almost entirely fail to supply men suited to the work. They neither care to collect, nor have they the skilled aptitude for observation. Then, though this country is possessed at home of incomparable stores of accumulated material, the class of competent amateurs who were mostly trained at our universities, and who did such good service in working that material out, is fast disappearing. It may not be easy, indeed, in the future to fill important posts even in this country with men possessing the necessary qualifications. But there was still another source of naturalists, even more useful, which has practically dried up. It is an interesting fact that the large majority of men of the last generation who have won distinction in this field have begun their career with the study of medicine. That the kind of training that natural history studies gives is of advantage to students of medicine which, rightly regarded, is itself a natural history study, can hardly be denied. But the exigencies of the medical curriculum have crowded them out; and this, I am afraid, must be accepted as irremediable. I can not refrain from reading you, on this point, an extract from a letter which I have received from a distinguished official lately intrusted with an important foreign mission. I should add that he had himself been trained in the old way.

"I have had my time, and must leave to younger men the delight of working these interesting fields. Such chances never will occur again, for roads are now being made and ways cut in the jungle and forest, and you have at hand all sorts of trees level on the ground ready for study. These bring down with them orchids, ferns, and climbers of many kinds, including rattan palms, etc. But excellent as are the officers who devote their energy to thus opening up this country, there is not one man who knows a palm from a dragon tree, so the chance is lost. Strange to say, the medical men of the Government service know less and care less for natural history than the military men, who at least regret they have no training or study to enable them to take an intelligent interest in what they see around them. A doctor nowadays cares for no living thing larger or more complicated than a *bacterium* or a *bacillus*."

But there are other and even more serious grounds why the present dominance of one aspect of our subject is a matter for regret. In the concluding chapter of the Origin, Darwin wrote: "I look with confidence to the future—to young and rising naturalists." But I observe that most of the new writers on the Darwinian theory, and, oddly enough, especially when they have been trained at Cambridge, generally begin by more or less rejecting it as a theory of the origin of species, and then proceed unhesitatingly to reconstruct it. The attempt rarely seems to me successful, perhaps because the limits of the laboratory are unfavorable to the accumulation of the class of observations which are suitable for the purpose. The laboratory, in fact, has not contributed much to the Darwinian theory, except the Law of Recapitulation, and that, I am told, is going out of fashion.

The Darwinian theory, being, as I have attempted to show, the outcome of the natural history method, rested at every point on a copious basis of fact and observation. This more modern speculation lacks. The result is a revival of transcendentalism. Of this we have had a copious crop in this country, but it is quite put in the shade by that with which we have been supplied from America. Perhaps the most remarkable feature is the persistent vitality of Lamarckism. As Darwin remarks: "Lamarck's one suggestion as to the cause of the gradual modification of species—effort excited by change of conditions—was, on the face of it, inapplicable to the whole vegetable world" (II, 189). And if we fall back on the inherited direct effect of change of conditions, though Darwin admits that "physical conditions have a more direct effect on plants than on animals" (II, 319), I have never been able to convince myself that that effect is inherited. I will give one illustration. The difference in habit of even the same species of plant when grown under mountain and lowland conditions is a matter of general observation. It would be difficult to imagine a case of "acquired characters" more likely to be inherited. But this does not seem to be the case. The recent careful research of Gaston Bonnier only confirms the experience of cultivators. "The modifications acquired by the plant when transported for a definite time from the plains to the Alps, or vice versa, disappear at the end of the same period when the plant is restored to its original conditions." (Ann. d. Sc. nat., 7^{e} sér. XX, 355.)

Darwin, in an eloquent passage, which is too long for me to quote (Origin, 426), has shown how enormously the interest of natural history is enhanced "when we regard every production of nature as one which has had a long history," and "when we contemplate every complex structure - - - as the summing up of many contrivances." But this can only be done, or at any rate begun, in the field, and not in the laboratory.

A more serious peril is the dying out amongst us of two branches of botanical study in which we have hitherto occupied a position of no small distinction. Apart from the staffs of our official institutions,

there seems to be no one who either takes any interest in, or appreciates in the smallest degree, the importance of systematic and descriptive botany. And geographical distribution is almost in a worse plight, yet Darwin calls it "that grand subject, that almost keystone of the laws of creation" (I, 356).

I am aware that it is far easier to point out an evil than to remedy it. The teaching of botany at the present day has reached a pitch of excellence and earnestness which it has never reached before. That it is somewhat one-sided can not probably be remedied without a subdivision of the subject and an increase in the number of teachers. If it has a positive fault, it is that it is sometimes inclined to be too dogmatic and deductive. Like Darwin, at any rate in a biological matter, "I never feel convinced by deduction, even in the case of H. Spencer's writings" (III, 168). The intellectual indolence of the student inclines him only too gladly to explain phenomena by referring them to "isms," instead of making them tell their own story.

ORGANIZATION OF SECTION.

I am afraid I have detained you too long over these matters, on which I must admit I have spoken with some frankness. But I take it that one of the objects of our section is to deliver our minds of any perilous stuff that is fermenting in it. But now, having taken leave of the past, let us turn to the future.

We start at least with a clean slate. We can not bind our successors, it is true, at other meetings. But I can not doubt that it will be in our power to materially shape our future, notwithstanding. When we were only a department, I think we all felt the advantage of these annual meetings, of the profitable discussion, formal and informal, and of the privilege of meeting so many of our foreign brethren who have so generously supported us by their presence and sympathy.

I am anxious, then, to suggest that we should conduct our proceedings on as broad lines as possible. I do not think we should be too ready to encourage papers which may well be communicated to societies, either local or central.

The field is large; the laborers, as they advance in life, can hardly expect to keep pace with all that is going on in it. We must look to individual members of our number to help us by informing and stimulating addresses on subjects they have made peculiarly their own, or on important researches on which they have been specially engaged.

NOMENCLATURE.

There is one subject upon which, from my official position elsewhere, I desire to take the opportunity of saying a few words. It is that of nomenclature. It is not on its technical side, I am afraid, of sufficient general interest to justify my devoting to it the space which its importance would otherwise deserve. But I hope to be able to enlist your

support for the broad, common-sense principles on which our practice should rest.

As I suppose, everyone knows we owe our present method of nomenclature in natural history to Linnæus. He devised the binominal, or, as it is often absurdly called, the binomial system. That we must have a technical system of nomenclature, I suppose no one here will dispute. It is not, however, always admitted by popular writers who have not appreciated the difficulty of the matter, and who think all names should be in the vernacular. There is the obvious difficulty that the vast majority of plants do not possess any names at all, and the attempts to manufacture them in a popular shape have met with but little success. Then, from lack of discriminating power on the part of those who use them, vernacular names are often ambiguous; thus Bullrush is applied equally to *Typha* and to *Scirpus*, plants extremely different. Vernacular names, again, are only of local utility, while the Linnæan system is intelligible throughout the world.

A technical name, then, for a plant or animal is a necessity, as without it we can not fix the object of our investigations into its affinity, structure, or properties. (Linn. Phil., 210.) "Nomina si nescis perit et cognitio rerum."

In order to get clear ideas on the matter, let us look at the logical principles on which such names are based. It is fortunate for us that these are stated by Mill, who, besides being an authority on logic, was also an accomplished botanist. He tells us (System of Logic, I, 132): "A naturalist, for purposes connected with his particular science, sees reason to distribute the animal or vegetable creation into certain groups rather than into any others, and he requires a name to bind, as it were, each of his groups together." He further explains that such names, whether of species, genera, or orders, are what logicians call connotative; they *denote* the members of each group and *connote* the distinctive characters by which it is defined. A species, then, connotes the common characters of the individuals belonging to it; a genus, those of the species; an order, those of the genera.

But these are the logical principles which are applicable to names generally. A name such as *Ranunculus repens* does not differ in any particular from a name such as John Smith, except that one denotes a species, the other an individual.

This being the case, and technical names being a necessity, they continually pass into general use in connection with horticulture, commerce, medicine, and the arts. It seems obvious that if science is to keep in touch with human affairs, stability in nomenclature is a thing not merely to aim at, but to respect. Changes become necessary, but should never be insisted upon without grave and solid reason. In some cases they are inevitable unless the taxonomic side of botany is to remain at a standstill. From time to time the revision of a large group has to be undertaken from a uniform and comparative point of view. It then

often occurs that new genera are seen to have been too hastily founded on insufficient grounds, and must therefore be merged in others. This may involve the creation of a large number of new names, the old ones becoming henceforth a burden to literature as synonyms. It is usual in such cases to retain the specific portion of the original name, if possible. If it is, however, already preoccupied in the genus to which the transference is made, a new one must be devised. Many modern systematists have, however, set up the doctrine that a specific epithet once given is indelible, and whatever the taxonomic wanderings of the organism to which it was once assigned, it must always accompany it. This, however, would not have met with much sympathy from Linnæus, who attached no importance to the specific epithet at all: "Nomen specificum sine generico est quasi pistillum sine campana." (Phil., 219.) Linnæus always had a solid reason for everything he did or said, and it is worth while considering in this case what it was.

Before his time the practice of associating plants in genera had made some progress in the hands of Tournefort and others, but specific names were still cumbrous and practically unusable. Genera were often distinguished by a single word: and it was the great reform accomplished by Linnæus to adopt the binominal principle for species. But there is this difference: Generic names are unique, and must not be applied to more than one distinct group. Specific names might have been constituted on the same basis; the specific name in that case would then have never been used to designate more than one plant, and would have been sufficient to indicate it. We should have lost, it is true, the useful information which we get from our present practice in learning the genus to which the species belongs; but theoretically a nomenclature could have been established on the one-name principle. The thing, however, is impossible now, even if it were desirable. A specific epithet like *vulgaris* may belong to hundreds of different species belonging to as many different genera, and taken alone is meaningless. A Linnæan name, then, though it consists of two parts, must be treated as a whole. "Nomen omne plantarum constabit nomine generico et specifico." (Phil., 212.) A fragment can have no vitality of its own. Consequently, if superseded, it may be replaced by another which may be perfectly independent.[1]

It constantly happens that the same species is named and described by more than one writer, or different views are taken of specific differences by various writers; the species of one are therefore "lumped" by another. In such cases, where there is a choice of names, it is

[1]As Alphonse de Candolle points out in a letter published in the Bull. de la Soc. bot. de France (XXXIX), "the real merit of Linnæus has been to combine, for all plants, the generic name with the specific epithet." It is important to remember that in a logical sense the "name" of a species consists, as Linnæus himself insisted, in the combination, not in the specific epithet, which is a mere fragment of the name and meaningless when taken by itself.

customary to select the earliest published. I agree, however, with the late Sereno Watson (Nature, XLVII, 54), that "there is nothing whatever of an ethical character inherent in a name, through any priority of publication or position, which should render it morally obligatory upon anyone to accept one name rather than another." And, in point of fact, Linnæus and the early systematists attached little importance to priority. The rigid application of the principle involves the assumption that all persons who describe, or attempt to describe, plants are equally competent to the task. But this is so far from being the case that it is sometimes all but impossible even to guess what could possibly have been meant.[1]

In 1872, Sir Joseph Hooker (Flora of British India, I, vii) wrote: "The number of species described by authors who can not determine their affinities increases annually, and I regard the naturalist who puts a described plant into its proper position in regard to its allies as rendering a greater service to science than its describer when he either puts it into a wrong place or throws it into any of those chaotic heaps, miscalled genera, with which systematic works still abound." This has always seemed to me not merely sound sense, but a scientific way of treating the matter. What we want in nomenclature is the maximum amount of stability and the minimum amount of change compatible with progress in perfecting our taxonomic system. Nomenclature is a means, not an end. There are, perhaps, 150,000 species of flowering plants in existence. What we want to do is to push on the task of getting them named and described in an intelligible manner, and their affinities determined as correctly as possible. We shall then have material for dealing with the larger problems which the vegetation of our globe will present when treated as a whole. To me the botanists who waste their time over priority are like boys who, when sent on an errand, spend their time in playing by the roadside. By such men even Linnæus is not to be allowed to decide his own names. To one of the most splendid ornaments of our gardens he gave the name *Magnolia grandiflora;* this is now to be known as *Magnolia fœtida*. The reformer himself is constrained to admit 'the change is a most unfortunate one in every way.' (Garden and Forest, II, 615.) It is difficult to see what is gained by making it, except to render systematic botany ridiculous. The genus *Aspidium*, known to every fern cultivator, was founded by Swartz. It now contains some 400 species, of which the vast majority were, of course, unknown to him at the time; yet the names of all these are to be changed because Adamson founded a genus, *Dryopteris*, which seems to be

[1]Darwin, who always seems to me, almost instinctively, to take the right view in matters relating to natural history, is (Life, Vol. I, p. 364) dead against the new "practice of naturalists appending for perpetuity the name of the *first* describer to species." He is equally against the priority craze: "I can not yet bring myself to reject very *well-known* names" (ibid., p. 369).

the same thing as *Aspidium*. What, it may be asked, is gained by the change? To science it is certainly nothing. On the other hand we lumber our books with a mass of synonyms, and perplex everyone who takes an interest in ferns. It appears that the name of the well-known Australian genus *Banksia* really belongs to *Pimelea;* the species are therefore to be renamed, and *Banksia* is to be rechristened *Sirmuellera*, after Sir Ferdinand von Mueller, a proposal which, I need hardly say, did not emanate from an Englishman.

I will not multiply instances. But the worst of it is that those who have carefully studied the subject know that from various causes, which I can not afford the time to discuss, when once it is attempted to disturb accepted nomenclature, it is almost impossible to reach finality. Many genera only exist by virtue of their redefinition in modern times; in the form in which they were originally promulgated they have hardly any intelligible meaning at all.

It can hardly be doubted that one cause of the want of attention which systematic botany now receives is the repulsive labor of the bibliographical work with which it has been overlaid. What an enormous bulk nomenclature has already attained may be judged from the Index Kewensis, which was prepared at Kew, and which we owe to the munificence of Mr. Darwin. In his own studies he constantly came on the track of names which he was unable to run down to their source. This the Index enables to be done. It is based, in fact, on a manuscript index which we compiled for our own use at Kew. But it is a mistake to suppose that it is anything more than the name signifies, or that it expresses any opinion as to the validity of the names themselves. That those who use the book must judge of for themselves. We have indexed existing names, but we have not added to the burden by making any new ones for species already described.

What synonymy has now come to may be judged by an example supplied me by my friend Mr. C. B. Clarke. For a single species of *Fimbristylis* he finds 135 published names under six genera. If we go on in this way we shall have to invent a new Linnaeus, wipe out the past, and begin all over again.

Although I have brought the matter before the section, it is not one in which this, or indeed any, collective assemby of botanists can do very much. While I hope I shall carry your assent with the general principles I have laid down, it must be admitted that the technical details can only be appreciated by experienced specialists. All that can be hoped is a general agreement among the staffs of the principal institutions in different countries where systematic botany is worked at; the free lances must be left to do as they like.

PUBLICATIONS.

I have dwelt at such length on certain aspects of my subject that perhaps, without great injustice, you may retort on me the complaint of

onesidedness. But when I survey the larger field of botany in this country, the prospect seems to me so vast that I should despair even if I had my whole address at my disposal of doing it justice. I think that its extent is measured by the way in which the publications belonging to our subject are maintained. First of all, we have access to the Royal Society, a privilege of which I hope we shall always continue to take advantage for communications which either treat of fundamental subjects, or at least are of general interest to biologists. Next to this we have our ancient Linnaean Society, with a branch of its publications handsomely and efficiently devoted to systematic work. Then we have the Annals of Botany, which has now, I think, established its position, and which brings together the chief morphological and physiological work accomplished in the country. Lastly, we have the Journal of Botany, a less ambitious, but useful periodical, which is mainly devoted to the labors of English botanists. I remember there was a time when I thought that this, at any rate, was an exhausted field. But it is not so; knowledge in its most limited aspects is inexhaustible if the laborer have the necessary insight. The discoveries of Mr. Arthur Bennett among the potamogetons of the eastern counties is a striking and brilliant instance.

Besides the publication of the Annals, we owe to the Oxford Press a splendid series of the best foreign text-books issued in our own language. If the thought has sometimes occurred to one's mind that we were borrowers too freely from our indefatigable neighbors, I at least remember that the late Professor Eichler paid us the compliment of saying that he preferred to read one of these monumental books in the English translation rather than in the original. I believe it is no secret that botany owes the aid that Oxford has rendered it in these and other matters in great measure to my old friend the master of Pembroke College, than whom I believe science has no more devoted supporter.

PALEOBOTANY.

I have said much of recent botany; I must not pass over that of past ages. Two notable workers in this field have passed away since our last meeting. Saporta was with us at Manchester, and we shall not readily forget his personal charm. If some of his work has about it a too imaginative character, the patience and entire sincerity with which he traced the origin of the existing forms of vegetation in southern Europe to their ancestors in the not distant geological past will always deserve attentive study. But in the venerable, yet always useful, Williamson we lose a figure whose memory we shall long preserve. With rare instinct he accumulated a wealth of material illustrative of the vegetation of the Carboniferous epoch, which, I suppose, is unique in the world. And this was prepared for examination with incomparable patience either by his own hands or under his own eyes. He illustrated it with absolute fidelity. And if he did not in describing it

always use language with which we could agree, nothing could ruffle either his imperturbable good nature or the noble simplicity of his character. Truth to tell, we were often in friendly warfare with him. But I rejoice to think that before his peaceful end came he had patiently reconsidered and abandoned all that we regarded as his heresies, but which were in truth only the old manner of looking at things. And I think that if anything could have contributed to make his departure happy, it was the conviction that the completion of his work and his scientific reputation would remain perfectly secure in the hands of Dr. Scott.

VEGETABLE PHYSIOLOGY.

Turning again to the present, the difficulty is to limit the choice of topics on which I would willingly dwell. In an address which I delivered at the Bath meeting in 1888, I ventured to point out the important part which the action of enzymes would be found to play in plant metabolism. My expectations have been more than realized by the admirable work of Professor Green on the one hand, and of Mr. Horace Brown on the other. The wildest imagination could not have foreseen the developments which in the hands of animal physiologists would spring from the study of the fermentative changes produced by yeast and bacteria. These, it seems to me, bid fair to revolutionize our whole conceptions of disease. The reciprocal action of ferments, developed in so admirable a manner by Marshall Ward in the case of the ginger-beer plant, is destined, I am convinced, to an expansion scarcely less important.

But, perhaps, the most noteworthy feature in recent work is the disposition to reopen in every direction fundamental questions. And here, I think, we may take a useful lesson from the practice of the older sections, and adopt the plan of intrusting the investigation of special problems to small committees, or to individuals who are willing to undertake the labor of reporting upon special questions which they have made peculiarly their own. These reports would be printed in extenso, and are capable of rendering invaluable service by making accessible acquired knowledge which could not be got at in any other way.

We owe to Mr. Blackman a masterly demonstration of the fact, long believed, but never, perhaps, properly proved, that the surface of plants is ordinarily impermeable to gases. Mr. Dixon has brought forward some new views about water movement in plants, which I confess I found less instructive than many of my brother botanists. They are expressed in language of extreme technicality; but as far as I understand them, they amount to this: The water moving in the plant is contained in capillary channels; as it evaporates at the surface of the leaves a tensile strain is set up, as long as the columns are not broken, to restore the original level. I can understand that in this way the "transpiration current" may be maintained. But what I want to know

is how this explains the phenomena in the sugar maple, a single tree of which will yield, I believe, 20 to 30 gallons of fluid before a single leaf is expanded.

We owe to Messrs. Darwin and Acton the supply of a "Manual of practical vegetable physiology," the want of which has long been keenly felt. Like the father of one of the authors, "I love to exalt plants" (I, 98). I have long been satisfied that the facts of vegetable physiology are capable of being widely taught, and are not less significant and infinitely more convenient than most of those which can be easily demonstrated on the animal side. How little any accurate knowledge of the subject has extended was conspicuously demonstrated in a recent discussion at the Royal Society, when two of our foremost chemists roundly denied the existence of a function of respiration in plants, because it was unknown to Liebig.

ASSIMILATION.

The greatest and most fundamental problem of all is that of assimilation. The very existence of life upon the earth ultimately depends upon it. The veil is slowly, but I think surely, being lifted from its secrets. We now know that starch, if its first visible product, is not its first result. We are pretty well agreed that this is what I have called a "protocarbohydrate." How is the synthesis of this effected? Mr. Acton, whose untimely end we can not but deeply deplore, made some remarkable researches, which were communicated to the Royal Society in 1889, on the extent to which plants could take advantage of organic compounds made, so to speak, ready to their hand. Loew, in a remarkable paper, which will perhaps attract less attention than it deserves from being published in Japan (Bull. College of Agric. Imp. Univ. Tokio, Vol. I), has from the study of the nutrition of bacteria arrived at some general conclusions in the same direction. Bokorny appears recently to have similarly experimented on algæ. Neither writer, however, seems to have been acquainted with Acton's work. The general conclusion which I draw from Loew is to strengthen the belief that form-aldehyde is actually one of the first steps of organic synthesis, as long ago suggested by Adolph Baeyer. Plants, then, will avail themselves of ready-made organic compounds which will yield them this body. That a sugar can be constructed from it has long been known, and Bokorny has shown that this can be utilized by plants in the production of starch.

The precise mode of the formation of form-aldehyde in the process of assimilation is a matter of dispute. But it is quite clear that either the carbon dioxide or the water, which are the materials from which it is formed, must suffer dissociation. And this requires a supply of energy to accomplish it. Warington has drawn attention to the striking fact that in the case of the nitrifying bacterium, assimilation may go on without the intervention of chlorophyll, the energy being supplied

by the oxidation of ammonia. This brings us down to the fact, which has long been suspected, that protoplasm is at the bottom of the whole business, and that chlorophyll only plays some subsidiary and indirect part, perhaps, as Adolph Baeyer long ago suggested, of temporarily fixing carbon oxide like hemoglobin, and so facilitating the dissociation.

Chlorophyll itself is still the subject of careful study by Dr. Schunck, originally commenced by him some years ago at Kew. This will, I hope, give us eventually an accurate insight into the chemical constitution of this important substance.

The steps in plant metabolism which follow the synthesis of the protocarbohydrate are still obscure. Brown and Morris have arrived at the unexpected conclusion that "cane sugar is the first sugar to be synthesized by the assimilatory processes." I made some remarks upon this at the time (Journ. Chem. Soc., 1893, 673), which I may be permitted to reproduce here:

"The point of view arrived at by botanists was briefly stated by Sachs in the case of the sugar beet, starch in the leaf, glucose in the petiole, cane sugar in the root. The facts in the sugar cane seem to be strictly comparable. (Kew Bulletin, 1891, 35–41.) Cane sugar the botanist looks on, therefore, as a 'reserve material.' We may call 'glucose' the sugar 'currency' of the plant, cane sugar its 'banking reserve.'

"The immediate result of the diastatic transformation of starch is not glucose, but maltose. But Mr. Horace Brown has shown in his remarkable experiments on feeding barley embryos that, while they can readily convert maltose into cane sugar, they altogether fail to do this with glucose. We may conclude, therefore, that glucose is, from the point of view of vegetable nutrition, a somewhat inert body. On the other hand, evidence is apparently wanting that maltose plays the part in vegetable metabolism that might be expected of it. Its conversion into glucose may be perhaps accounted for by the constant presence in plant tissues of vegetable acids. But, so far, the change would seem to be positively disadvantageous. Perhaps glucose, in the botanical sense, will prove to have a not very exact chemical connotation.

"That the connection between cane sugar and starch is intimate is a conclusion to which both the chemical and the botanical evidence seems to point. And on botanical grounds this would seem to be equally true of its connection with cellulose.

"It must be confessed that the conclusion that 'cane sugar' is the first sugar to be synthesized by the assimilatory processes seems hard to reconcile with its probable high chemical complexity, and with the fact that, botanically, it seems to stand at the end and not at the beginning of the series of metabolic change."

PROTOPLASMIC CHEMISTRY.

The synthesis of proteids is the problem which is second only in importance to that of carbohydrates. Loew's views of this deserve attentive study. Asparagin, as has long been suspected, plays an important part. It has, he says, two sources in the plant. "It may either be formed directly from glucose, ammonia (or nitrates), and sulphates, or it may be a transitory product between protein decomposition and reconstruction from the fragments" (loc. cit., 64).

In the remarks I made to the Chemical Society, I ventured to express my conviction that the chemical processes which took place under the influence of protoplasm were probably of a different kind from those with which the chemist is ordinarily occupied. The plant produces a profusion of substances, apparently with great facility, which the chemist can only build up in the most circuitous way. As Victor Meyer (Pharm. Journ., 1890, 773) has remarked: "In order to isolate an organic substance we are generally confined to the purely accidental properties of crystallization and volatilization." In other words, the chemist only deals with bodies of great molecular stability; while it can not be doubted that those which play a part in the processes of life are the very opposite in every respect. I am convinced that if the chemist is to help in the field of protoplasmic activity he will have to transcend his present limitations, and be prepared to admit that as there may be more than one algebra, there may be more than one chemistry. I am glad to see that a somewhat similar idea has been suggested by other fields of inquiry. Professor Meldola (Nature, XLII, 250) thinks that the investigation of photochemical processes "may lead to the recognition of a new order of chemical attraction, or of the old chemical attraction in a different degree." I am delighted to see that the ideas which were floating, I confess, in a very nebulous form in my brain are being clothed with greater precision by Loew.

In the paper which I have already quoted, he says of proteids (loc. cit., 13): "They are exceedingly labil compounds that can be easily converted into relatively stable ones. A great lability is the indispensable and necessary foundation for the production of the various actions of the living protoplasm for the mode of motions that move the life machinery. There is a source of motion in the labil position of atoms in molecules, a source that has hitherto not been taken into consideration either by chemists or by physicists."

But I must say no more. The problems to which I might invite attention on an occasion like this are endless. I have not even attempted to do justice to the work that has been accomplished among ourselves, full of interest and novelty as it is. But I will venture to say this, that if capacity and earnestness afford an augury of success, the prospects of the future of our section possess every element of promise.

ZOOLOGY SINCE DARWIN.[1]

By Ludwig v. Graff.

We of the younger generation, whose scientific training began within the domain of Darwinism, can only with difficulty realize what an agitation was produced almost forty years ago in the "descriptive" natural sciences by Darwin's Origin of Species.[2] It fell like a thunderbolt in a quiet period of descriptive work, when it was commonly thought that the philosophical ideas of the early part of the century were airy plays of fantasy, undemonstrated and undemonstrable, and that all speculation should therefore be distrusted, while the solid ground of fact should be clung to with anxious care.

How the theory of natural selection suddenly vivified that dry description, what wings it lent to the scalpel of the anatomist, and what wide vistas did it open to the eyes of the systematists, already becoming so shortsighted!

The mummies of species which filled our collections, each fenced off from each by well-arranged Latin diagnoses, were suddenly linked together by blood relationship. The fossil remains of extinct forms—hitherto shut out from the common realm of living things—were endowed with flesh and blood and arranged with the fauna and flora of to-day in a single great family tree representing the entire history of life upon the globe.

It is indeed well known that the idea of a natural, genealogical descent of existing animals and plants from the simplest primitive forms was expressed long before Darwin, and was specially and

[1] A discourse delivered by Prof. Ludwig von Graff on the occasion of his formal inauguration as rector magnificus of the Imperial Royal Charles Francis University at Graz, November 4, 1895. Translated from original, "Die Zoologie seit Darwin," Graz, 1896.

[2] The Origin of Species by Means of Natural Selection, or the Preservation of Favored Races in the Struggle for Life, by Charles Darwin. London, 1859. Translated into German by J. V. Carus under the title: "Charles Darwin ueber die Entstehung der Arten durch naturliche Zuchtwahl, oder die Erhaltung der begünstigen Rassen im Kampfe um's Dasein," Stuttgart, 1859.

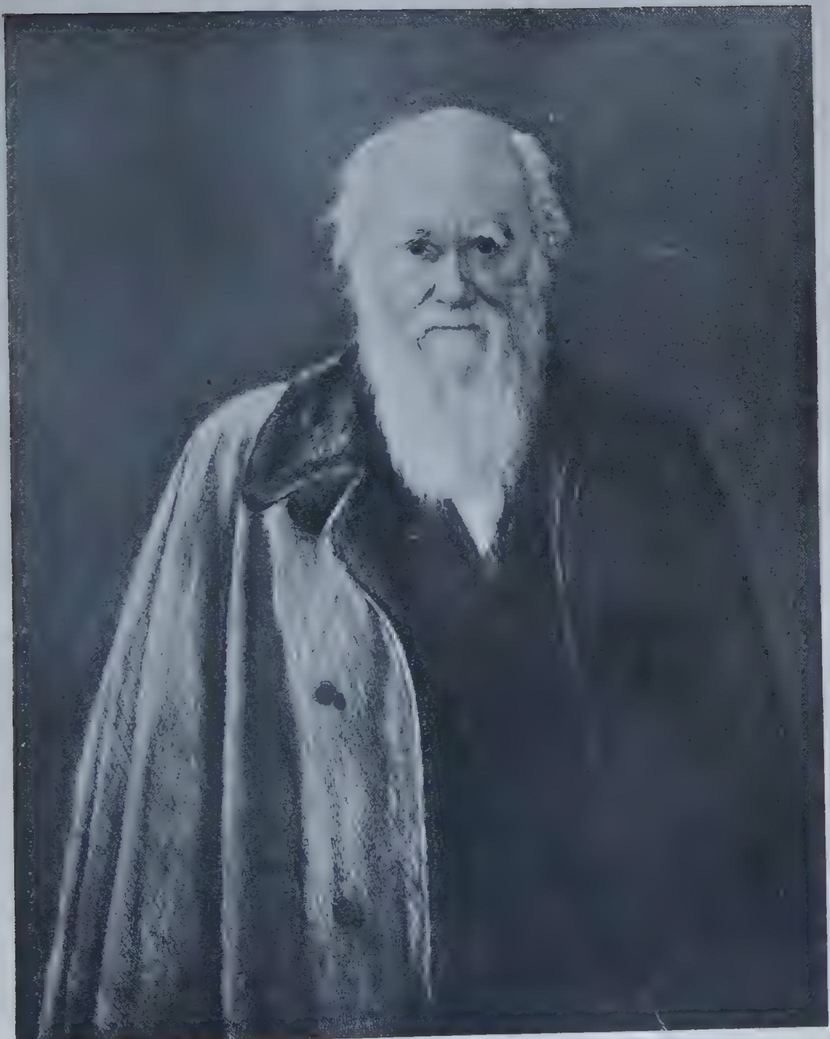
thoroughly formulated by Lamarck.[1] But the theory of natural selection proposed by the illustrious Briton for the first time attempted to place it on a scientific basis. The manifest phenomena of inheritance and variation are the main supports of his bold doctrine, the axis on which revolves the great loom of life which is propelled by the struggle of all living things to maintain themselves and to bring forth new life. The cause of the countless varieties of suitably modified forms has been made clear by Darwin, for he has shown that both the maintenance of the individual and that of the species require a perpetual struggle with the influences of the environment and with competing individuals, a struggle in which that only survives which is best adapted and most suitable to the existing conditions. Therefore there occurs a natural selection, the existing species undergoing an adaptation, a transformation, a division, and a completion. In the course of the immeasurably great spaces of time which have elapsed since the appearance of the first elementary living being, there has arisen the entire ascending series of vegetable and animal organisms, at whose head man now regards himself.

The Darwinian theory has become common property, and we can trace its influence in almost all departments of intellectual activity. Its opponents—who, by the way, outside the circle of naturalists, did not combat in Darwin so much his own work, the theory of selection, as the older theory of descent—have become ever fewer and more quiet as the doctrine has ceased to be put forward as a definite philosophical theory of life and has become the object of special scientific investigation. And the time appears to be not far distant when the Darwinian theory will be no more considered as a matter for controversy than is the Copernican theory of the solar system.

We can, therefore, dispassionately turn to the question, "What influence has Darwin's work had upon the development of zoology?"

First, it should be pointed out that the Darwinian theory encountered the two great branches of natural history under very different conditions. While in the science of botany, physiology had already obtained its proper place, there still prevailed in zoology a tendency to exclusive systematic morphology. What wonder that a doctrine whose highest aim consisted in the elucidation of forms should effect a much more powerful evolution in zoology than in botany! That Darwin himself was specially trained as a zoologist and hence took most of his examples from the animal kingdom, and that, besides, the phenomena of the "struggle for existence," as well as those of "natural selection," are much more striking and manifold in that domain than in the vegetable kingdom, should be considered as secondary causes in explaining why the Darwinian theory took so much quicker and deeper root in zoology than in botany.

[1] J. Lamarck, Philosophie zoologique, Paris, 1809. Translated into German by A. Lang under the title: "Zoologische Philosophie von Jean Lamarck, nebst einer biographischen Einleitung von Charles Martins." Jena, 1876.



CHARLES DARWIN. (1809–1882.)

(From the etching by Flameng after portrait by Collier.)

Finally, however, it affected both in the same way, and there are but few examples in the history of the development of the human mind that show such a revolution in the elementary principles of a science as the theory of natural selection has affected in the above-mentioned studies. Instead of being contented with mere description and lucid arrangement, there was undertaken the higher task of determining the causal relations of forms: ant-like descriptive industry had to associate itself with the comparative method; the eye had to seek assistance from the imagination.

As the first and most urgent task, appeared the changing of the classification hitherto followed according to the lines laid down by Linnaeus and Cuvier into one which should correspond with the history of the descent of living beings. The fiery spirit of E. Haeckel tried to accomplish this, when, in his brilliantly devised system of the organic natural sciences, the General Morphology of Organisms,[1] he attempted to determine the primitive stocks. However rash this may have been, considering the state of zoology at that time, it rendered an inestimable service by giving the first impulse toward that great development of animal morphology that has taken place during the last decade. Modern morphology first dates from that time, when, as formerly stood Schiller and Goethe, Haeckel, and Gegenbaur worked side by side. Since that time it has become so essential a part of scientific zoology that the text-books of to-day are only too much given up to comparative morphology.

The "fundamental law of biogeny" formulated by Haeckel, namely, that ontogeny (the development of the individual) is a short recapitulation of phylogeny (the development of the stock), soon dominated all branches of zoology, controlling comparative anatomy, embryology, and paleontology. Since the ancestral stages traversed by an animal are repeated in a more or less recognizable manner in the transitory forms assumed during the development of each individual, so embryology came in the post-Darwinian times to be considered as a necessary study. To this is chiefly due the enormous increase in zoological publications, which, during the period from 1845 to 1860, amounted to a yearly average of 2,900, but in that from 1860 to 1880, increased to about 5,400 per year.[2]

Simultaneously with this increase in literary production, there occurred an improvement in the technical methods of research. Innumerable staining methods enabled the investigator to study more accurately the structure of the cell, to separate its nucleus from its plasma, as also to define the constituent portions of each according to their various susceptibilities to staining.

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[1] E. Haeckel, Generelle Morphologie der Organismen, Berlin, 1866.

[2] As a basis for this calculation, I have used J. V. Carus and W. Englemann, "Bibliotheca zoologica" Leipzig, 1861, and O. Taschenberg, "Bibliotheca zoologica," II, Leipzig, 1887–1896.

The tissues of the body, such as muscle, nerve, and connective tissue, indeed the cells of a single organ acting under separate functional conditions, as those of glands, were separated from each other in the microscopical field by means of newly invented methods of staining and impregnation. The old methods of teasing and compressing tissues were superseded by the microtome, which has become indispensable in these investigations because it enables us to divide an animal into an unbroken series of extremely thin slices. Since by such means one can again restore after section the structure of objects even as to their most elementary parts, we obtained the means of investigating the intimate structure of animals whose small size had hitherto made it impossible to dissect them with the scalpel and whose opacity prevented us from obtaining any information concerning them by the compression method. A great advance was also made in the efficiency of the microscope by the construction of apochromatic lenses.

These all redounded to the benefit of morphology and at no previous period of zoology were there produced so many comprehensive and exhaustive monographs on zootomic and embryological subjects. The purpose of most of these was the establishment of the ancestral tree. But while comparative anatomy was of the first importance in the elucidation of the relationships of existing living forms, embryology lent itself particularly to the task, because it assisted to fill the gaps in the paleontogical record, by comparing the older stages of animal life with the phases of individual development. One result of this activity was the theory of the *homology of the germinal layers*. As certainly as the egg of all animals has the morphological value of a cell and points to unicellular primitive beings (protozoa) as the beginning of all higher organization, so surely must also the subsequent embryonal stages of multicellular animals (metazoa) afford reminiscences of common ancestral forms. And Haeckel, starting from this premise, believed that in the "gastrula" developmental stage—a widely extended form consisting of two concentric cell layers and a primitive mouth—he had, in fact, found the type of that ancestral form common to all multicellular animals (the Gastræa).[1] Its two cell layers must necessarily have the same morphological value in all, and thereby was presented the possibility of tracing the homology of organs, not only in single stocks, but also throughout the entire kingdom of the metazoa.

But when we examine the facts cited in support of this wide-reaching generalization, we are obliged to admit that it has not as yet been established. The more profound our embryological knowledge becomes, and the more exact our comparative researches are, the higher loom the difficulties. But the essential trouble lies not so much in the difficulty of readily bringing under the gastrula scheme all the observed

[1] E. Haeckel, "Die Gastræa-Theorie, die phylogenetische Classification des Thierreichs und die Homologie der Keimblatter" (Jenaische Zeitschrift für Naturwissenschaft, VIII. Bd., Jena, 1874).

phases of development, nor in the circumstance that organs of developed animals having similar structure and formation arise from different germinal layers, but in the fact that the primary germinal layers arise not only in different related animal stocks, but sometimes even within one and the same phylum, in such a diverse manner that it would certainly be a reversal of the old conception of homology[1] if, in spite of this, they should be considered as morphological equivalents.

The morphological point of view, which has hitherto exclusively prevailed, will hardly serve us in this case. Experimental inquiry must first, tracing out the causes of the different kinds of development, seek to make clear to us "the internal mechanism of the phenomena." Only in this way can we succeed in properly separating the "kenogenetic," or secondary, deceptive changes of form from the "palingenetic" characters that represent originally inherited, developmental phases.[2] And until a more solid foundation for this shall be obtained, the theory of the germinal layers, that has often been advanced with so much confidence, can not be authoritatively formulated.

Of double value, therefore, appear the facts that have been contributed to morphology from another phylogenetic source, that of the natural history of extinct forms. Once an accessory of geology, this has, during the period that we are considering, been developed into an independent branch of study, and has borne richer and richer fruit in proportion as it has recognized the necessity of correlating its advances with the knowledge of living animals.[3]

Zoology and paleozoology have both the same chief aim—the elucidation of the history of the animal forms of our globe, and a collection corresponding to modern views, which require a complete representation of the material available for reconstructing the history of the race, ought to place, side by side with the forms of animals now living, the petrified remains of their ancestors. The generalized types, transition

[1] C. Gegenbaur, the master of comparative anatomy, describes homology (special homology) as "the relation between two organs that had a common origin; that is to say, have been developed from a similar primitive form," and a complete homology exists "whenever the organ in question, however it may be modified in shape, size, and other relations, has constantly maintained its position and connections unchanged." (Grundzüge der vergleichenden Anatomie, 2 Aufl., pp. 80–81, Leipzig, 1870.)

[2] E. Haeckel, "Die Gastrula und die Eifurchung der Thiere" (Cap., Die Bedeutung der Palingenie und der Cenogenie). (Jenaische Zeitschrift für Naturwissenschaft, IX. Bd., Jena, 1875.)

[3] K. v. Zittel has been especially active in conducting paleontology into this new path. By his teaching and researches, as well as by the exemplary arrangement of the state paleontological collection in Munich, V. Zittel has continually worked to secure the intimate cooperation of paleozoology and zoology, and his well-known "Grundzüge der Paläontologie" (München und Leipzig, 1895) is directed to the same end. Compare also K. v. Zittel, "Die Paläontologie und das biogenetische Grundgesetz," in "Aula." Wochenblatt für die Akadem. Welt, I. Jahrg., page 385 et seq. München, 1895; as well as F. v. Wagner's review in the Biologische Centralblatt, XI. Bd., p. 840 et seq., Leipzig, 1895.

forms, and complete series of successive developments, with which paleontology has supplied us, are all the more valuable because the exactitude of its descriptions, resting in part upon petrified material, and the ease with which its fundamental facts can be reverified, lend to most paleontological expositions a certainty and trustworthiness that must often be denied to those that relate to the morphology of recent animals.

Darwin has carefully avoided the consideration of a number of questions whose discussion is of no great weight for his theory of selection. So it is, in fact, of no importance for the latter what our conceptions may be as to the origin of the simplest forms of life upon the earth, if we only establish indubitably that such did exist. So also the theory of descent, as well as the theory of selection, is unaffected by the fact that at the time they were first advanced there was no intelligible conception of the material basis of heredity, nor of the causes of variation. The actual existence of these processes sufficed, and served as a satisfactory basis for the theory. As soon, however, as—first by German naturalists and philosophers—the theory of descent was expanded to a new system of biological philosophy, these important questions were necessarily brought forward for discussion.

As regards the first of these questions, the *primary evolution of organisms*, we have not yet been able to formulate a satisfactory theory. As there are no chemical elements or "vital materials" peculiar to living beings, and no special "vital force" has been demonstrated, there remains only the supposition that the first evolution of the simplest organisms must have taken place from inorganic material by the action of the forces that operate in its own domain. As, however, the material basis of vital processes, protoplasm, consists of combinations of carbon belonging to the group of albuminoid bodies, the attempt was made to refer the phenomena of movement that characterize life to the peculiar chemico-physical peculiarities of carbon. But neither this so-called *carbon theory* of Haeckel, nor the endeavor made in recent years by O. Bütschli and others to imitate by artificial mixtures[1] the structure and movements of protoplasm, informs us how a mixture of dead albuminoid compounds can become *living* protoplasm.

A conception in any way satisfactory as to the first evolution of living beings must be still more difficult at this time, as not only can chemistry afford us no satisfactory insight into the molecular structure of protoplasm, but it appears from theoretical considerations that the much-cited "simple lump of protoplasm" may have a highly complicated

[1] O. Bütschli, Untersuchungen über mikroskopische Schäume und das Protoplasma. Versuche und Beobachtungen zur Lösung der Frage nach den physikalischen Bedingungen der Lebenserscheinungen, Leipzig, 1892, as well as later publications of the same author in the Verhandlungen des naturh. medicinischen Vereins zu Heidelberg.

structure and should not, without further evidence, be compared to an albuminoid mixture.

By this time the enthusiasm which hailed bathybius as the representative of Oken's "primitive slime," an undifferentiated protoplasmic mass covering the bottom of the ocean, has considerably cooled.[1] The alleged nonnucleated primitive beings disappear more and more since we have had the means of demonstrating the cell nucleus where it had escaped observation when treated by the technical methods formerly used, and the hypothesis of "free cell formation" in organic fluids has given place to the maxim "omnis cellula e cellula."

There will, then, on the day when we learn that the last of the moners possesses a nucleus like other cells, be seen a much greater gap between the simplest known living being and the inorganic individual—the crystal—than is realized to-day.

Zoology has obtained more satisfactory results from the numerous researches, which, either with or without the knowledge of their conductors, contributed to bring nearer to a solution the problems of heredity and variation.

Darwin considered heredity as a fact of experience demonstrated by the specific similarity of child and adult, without attempting to seek for its material vehicle.[2] Since, however, all living beings are made up of cells, and even the most complicated organism has at the beginning of its development the morphological value of a single cell, such a vehicle can be only a part of a cell To find it we must have a deeper insight into the structure of the cell and into the significance of its various parts.

For example, as soon as the structure of the cell substance and that of the nucleus which it contains were investigated by the new methods, the surprising discovery was made that movement and irritability, as well as respiration, are functions that the cell substance exercises independently from the nucleus; that, on the contrary, assimilation and secretion take place only under the influence of the latter and that the nucleus is the only organizing morphogenic factor of the cell. Further investigations showed that the cell consists of two substances, chromatin and achromatin, distinguished by their behavior with staining fluids, the first of which plays an important rôle in cell division, as its distribution inaugurates the multiplicative process and leads through a regular succession of metamorphoses (mitosis) first to the bipartition of the nucleus, and then to that of the extranuclear cell substance.

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[1] The bathybius, recently discovered by Bessels, appears to be nothing more than a plasmodium-like organism having only a local distribution. (See Bronn's Classen und Ordnungen des Thierreichs, Protozoa, recently reedited by O. Bütschli, pp. 179-181. Leipzig and Heidelberg, 1880.

[2] The pangenesis hypothesis of Darwin, which supposed that the germ was influenced by the form of the body which held it as well as by external conditions of existence by means of small particles attracted to it from all parts of the body, is without any evidential basis, and is, as Weismann (Germplasma, p. 7) has remarked, more a statement than a solution of the question of heredity.

The conclusion that chromatin is the special vehicle of heredity could not, however, be brought forward with convincing precision until bisexual (digenous) propagation was studied. Here, where two cells, usually of very different shape, unite to form the impregnated egg, it is proved that during the act the chromatin of the latter is formed in equal proportions from the chromatin of the two parent cells.

So the century-old problem of fecundation has been solved, a problem whose history shows in the most instructive and at the same time amusing manner how preconceived ideas may becloud observation, and how ingenious the human mind is when it tries to replace the want of facts by dialectics.

The researches on cell division and fecundation, together with the tendency to phylogeny, have given to the post-Darwinian period of zoology its character. They are among the most glorious achievements in the realm of natural science. Those who in the zoological field have specially interested themselves in these investigations—W. Flemming, O. and R. Hertwig, Ed. van Beneden—have for the first time made it possible to formulate a theory of heredity. For, however important may be the knowledge quite recently acquired that all changes in the chromatin are passive, conducted and controlled by a newly discovered source of power, the "centrosome," it can in no way change our conception of the chromatin as the substance by which the parental qualities are transmitted.

As all cell nuclei are derived from the nucleus of the egg, every cell of the body must contain a minute portion of the parental chromatin and thereby is secured the transmission of the parental qualities. Upon this basis is founded A. Weismann's theory of heredity,[1] which has certainly performed one service that can not be controverted, in that it has at last clearly formulated the question.

Are the lines of development exactly predetermined by the constitution of the germ, or is the germ to a certain extent an indifferent constructive material, whose future shaping depends solely upon the conditions of existence to which it is exposed?

On the one hand, the derivation of existing living forms from ancestors dissimilar in shape, and, on the other, the phenomena of heredity which teach us that parent and child, or to express it otherwise, the successive generative cycles of the same species, always pass through specifically similar morphological states, enable us to find an answer to these questions. It is expressed thus by the orthodox Darwinians: Every organism is a resultant of heredity and adaptation—what the parent inherits he transmits wholly to the child, but he adds thereto what he has himself acquired.

[1]A. Weismann: Das Keimplasma, eine Theorie der Vererbung, Jena, 1892. Among the other numerous writings of this author on the same subject the following are especially worthy of attention: Die Allmacht der Naturzüchtung, eine Erwiderung an Herbert Spencer, Jena, 1893; Äussere Einflüsse als Entwicklungsreize, Jena, 1894; Neue Gedanken zur Vererbungsfrage, Jena, 1895.

On the contrary, Weismann's neo-Darwinism denies the inheritance of acquired characters, and there exists no well-authenticated fact that contradicts his views nor any theory that can give a plausible explanation of the transmission to the organs of the body of new structural elements for the germ cells.

Should we accept this inheritance of acquired characters, or, what is the same thing, an immediate morphogenic and hereditarily transmissible action of external forces, then it would be equivalent to admitting the possibility of the production of new living and fertile animal forms of the most varied kinds by changing the conditions of existence in the eggs of the same species. This is the last consequence, and one contrary to all experience, of the hypothesis that external conditions are the factors that determine form.

Oscar Hertwig and Y. Delage seek to avoid this conclusion, which they also recognize as absurd, by tracing back the essential similarity of child and parent to the specific chemico-physical constitution of the germ-plasm derived from the latter.[1] The derivation of a species from the germ of another is prevented because every germ must perish that does not find the environment adapted to its specific constitution. But this is only removing the causes of morphogenesis to the intimate constitution of the germ.

To attribute the same causal significance to these true causes of morphogenesis which lie in the intimate constitution of the germ as to the influence of external conditions is, however, evidently arbitrary, and indicates, as F. v. Wagner has quite recently[2] justly remarked, a

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[1] Y. Delage. La stucture du protoplasma et les théories sur l'hérédité et les grands problèmes de la biologie générale. Paris, 1895. Delage's views on the heredity question are the exact opposite of those of Weismann. Characteristic of this is Delage's statement that for the elucidation of the morphological and physiological agreement between parent and child we no more need to accept a tendency to inheritance residing in the germ than we do to explain why the cadaver of an earthworm, of an insect, of a frog, and of a mammal under the same external conditions all pass in the same way, typical for each animal named, through the processes of decomposition.

O. Hertwig, Präformation oder Epigenese? Grundzüge einer Entwicklungstheorie der Organismen. Jena, 1894. Hertwig harmonizes the opposing views of Weismann and Delage, in that he does not assign the causes of the generation of form either exclusively to the germ, nor exclusively or preponderatingly to the environment, but gives to each an equal determining value. Hertwig himself says of his theory (pp. 132–133): "This theory may be called evolutionary, because it accepts for the basis of the processes of development a specific and highly organized primitive substance; it is, on the contrary, epigenetic in so far as it considers that the primitive substance increases only by the fulfillment of innumerable conditions, in which, for example, I include the chemical processes that begin with the first segmentation of the cell, gradually shaping itself, step by step, till it finally produces a maturely developed result as different from its first primitive condition as the completely organized plant or animal is from the single cells which compose it."

[2] F. v. Wagner, Einige Bemerkungen zu O. Hertwig's Entwicklungs-Theorie (Biologisches Centralblatt, XV Bd., pp. 777–815, Leipzig, 1895). The same, Das Problem der Vererbung ("Aula" Wochenblatt für die Gebildeten aller Stände, I. Jahrg., Nr. 24 und 25, München, 1895).

confounding of cause and condition contrary to the ordinary use of the terms.

Systematic zoology and the comparative anatomy of living beings show us that the possibilities of development for germs are almost infinitely varied, and though any particular germ can only pass over the same path as did the innumerable generations of its ancestors, this can only be due to internal causes; that path must have been there ready to be traversed; that is to say, there must be fixed external circumstances (conditions) present if the causes are to make their operation manifest.

E. Haeckel has said[1] that with the inheritance of acquired peculiarities the entire theory of descent must stand or fall. This would only be correct if there were no other explanation for the variability of organisms. But Weismann does not deny that the conditions of existence may have an alterative influence upon the constitution of the germ-plasm, and during long spaces of time many components of the congeries of forces belonging to the latter may increase in power, others decrease; indeed even new sources of force may be introduced. But these operations are direct and not caused by the action of any of the other organs of the body.

To support the hypothesis of such a direct influencing of the germ-plasm by external agents, we are forced to refer to those organisms that are propagated asexually (monogenically), for in germs which are produced bisexually (digenically) there are already possible, because of the intermixture of hereditary material from two different parents, an extraordinary number of combinations in the composition of the germ-plasm, so many that it is probable that the separation of a portion of the nucleus (the polar bodies), which is observed to occur before the beginning of segmentation, is an operation for the elimination of a superfluous number of hereditary tendencies.[2]

The cause of variation lies, therefore, in the individual changes that occur in the composition of the germ-plasm, and what we call "adaptation," is not an active and immediate achievement of a single individual, but the result of a more or less complicated process of selection that extends throughout generations of individuals. The external conditions, to whose influence animals respond in a definite manner peculiar and appropriate for each species, are therefore in no way the true causes of such reactions, but merely release a morphogenic force that already resides in the germ and can only be put in action by just these precise circumstances.

If we accept the view here presented, there will be noted a remarkable contrast between the germ cells and the "soma," that multiform

[1] E. Haeckel, Zur Phylogenie der australischen Fauna; Systematische Einleitung. In R. Semon, Zoologische Forschungsreisen in Australien und dem malayischen Archipel, I. Bd., Jena, 1887.

[2] A. Weismann, Über die Zahl der Richtungskörper und über ihre Bedeutung für die Vererbung. Jena, 1887.

and often extraordinarily complicated assemblage of the remaining organs of the body. It is in this, that in the segmentation that has occurred during the preceding development of the ovum, those cells which are to play the part of germ cells in the future mature organism have assigned to them all portions of the ovum necessary for the reconstruction of the entire body, while to the somatic cells only those substances are assigned which are required for the construction of a definite organ or apparatus. In this way the soma becomes eventually an organ of the propagating cells that completes the work of metabolism, moves, feels, and thinks, but yet only serves, as may be said, for the evolution of the germ cells and so assures the continuity of life.

Since we have seen what are the chief new lines along which zoology has developed since Darwin's time, we may now be permitted to consider what modifications have been given to the old problems, once the only ones, namely, the description of the existing material of animal forms and the observation of their life history; that is to say, systematic natural history and biology in the restricted sense. The latter, although it had been for a long time neglected, gave the theory of natural selection a new and mighty impulse. It has been for this science a flourishing period, which can only be compared with that epoch at the end of the eighteenth century when were made the striking discoveries of Reaumur, Roesel, De Geer, Bonnet, Schäffer, and others. How important now, from a Darwinian point of view, were the correlation of animals with each other and with plants, the influence of climate and food and of light and heat to the struggle for existence, and to the phenomena of natural selection! The entire world offered material for this study, and there appeared books like H. W. Bates's Naturalist on the River Amazon and A. R. Wallace's Malay Archipelago, which were models for biological studies. A great number of excellent English and German investigators applied themselves to this work and found in the biologic history of plants and animals ever new evidence of the truth of the Darwinian theory, yet at the same time often encountering puzzling phenomena whose elucidation has baffled the acuteness of naturalists even to the present time. It is evident that here, as in other departments, we have not yet reached the end of knowledge, or, better, that of search for knowledge, and of means for investigating the truth.

Under biological facts there was formerly always placed geographical distribution. This was, indeed, only because it was customary to explain faunal variations by referring their causes to environmental conditions. As these did not usually afford a plausible explanation, zoogeography was essentially a collection of lists whose perusal was of not much more value to zoologists than a glance through a menagerie. The new foundation for the theory of descent has made a fundamental change in this, as it makes possible for the first time a scientific treatment of the facts of zoogeography. The faunal character of a region is determined by its geological age, the phylogenetic condition of the animal kingdom at the time of its deposition and its varying

geographical relations to other faunal areas during the different phases of the earth's history. It follows from this that it is not so much the phenomena of adaptation as the phylogenetic forces that are of the first importance in determining the typical character of a fauna. Zoogeography becomes, therefore, an important branch of phylogeny.[1] A. R. Wallace brought forward this conception in his famous work, The Geographical Distribution of Animals,[2] and he thereby becomes the master teacher of modern zoogeography. As a preliminary for its further extension it appears to be necessary to pursue with the utmost conscientiousness the laborious and petty task of systematically describing species.

Descriptive systematic zoology has not gained from the new doctrine so much directly as indirectly, through the general increase of interest in zoology and botany which led to more work in these branches than ever before. Besides, it would be easy to show that the colossal increase in our inventory of animal forms, rising from about 50,000 species in 1832 to about 150,000 to-day, should be ascribed not only to the greater number of investigators in the field, but also to the development of geography. Since the latter has been promoted from a servant of history to the rank of an independent science, and oceanographic questions have become prominent, those great expeditions have been organized which have given a wider character to the zoology of this period. When we learn that as regards marine life the *Challenger* expedition of 1872–1876 alone obtained nearly 8,000 new species, we are involuntarily reminded of the times of Piso, Marcgravius, and Bontius, who at the beginning of the seventeenth century astonished mankind by showing for the first time pictures of the dodo and of "homo sylvestris" brought from "both Indies." The description of these species gave hundreds of new races, families, and orders; and, published in thirty-two quarto volumes with 2,629 plates, kept 60 zoologists of all the cultivated nations employed for twenty years.[3] The result of this single

[1] In geographical distribution, the genealogical relations come out with special clearness in those cases where it can be shown that there is a regular proportion between the geographical separation and the morphological differences. This important conformity to law was first stated by H. Spitzer in his excellent Beiträge zur Descendenztheorie (Leipzig, 1886), and was shown to exist in the orders of apes and struthious birds (p. 259 et seq.). This relation ought to be demonstrable in many other groups of the animal kingdom. It may be stated that one of the most decided opponents of the transformistic theory of descent, A. Wigand, has made his agreement to that doctrine dependent upon the possibility of proving such a relation between geographic separation and morphological difference. (A. Wigand, Der Darwinismus und die Naturforschung Newton's und Cuvier's. Braunschweig, 1874–1877.)

[2] Authorized German edition by A. B. Meyer, two volumes. Dresden, 1876.

[3] Report on the scientific results of the voyage of H. M. S. *Challenger* during the years 1872–1876, under the command of Capt. Sir George A. Nares and the late Capt. Frank Tourle Thompson. Prepared under the superintendence of the late Sir C. Wyville Thomson, and now of John Murray. Fifty vols. 4°, London, 1880–1895.

expedition has increased the number of known species in many groups of animals four or five fold.

The increase in the collective number of forms described has had, in the first place, one result, in that it has obtained for the description of species a wider basis and a more positive meaning, in contrast to the Linnæan principle, that, looking only to practical exigencies of the moment, declared that new species must be separated from those already known by means of well-marked characters. We must now seek such a conception of specific qualities as may enable us to separate each specific form from those yet to be discovered. This requirement, which was already considered by careful systematists before the time of Darwin, is especially difficult, and can not be met unless one possesses the sense of form required for an artist. But at the same time the Darwinians often fell into a willful neglect of systematic work, a neglect which arose from despising the hair-splitting systems of the museums which were commonly unfriendly to the new theory, partly from exaggerated ideas of the fluidity of species—ideas which led to the most extraordinary abortions in the systematic field.

Happily, this period of fermentation is over, and we are learning again to prize systematic description as it is, for example, employed in the too long neglected science of entomology. We need these methods not only for the purpose of lending depth to our studies through the more extended retrospect of comparative anatomy and embryology, but in order to better express, by means of a system, the natural relationship of forms. One thing is certain, that the minutiose recital of diagnostically important external characters, which is customary in entomology, has done much less harm than the neglect with which external form relations have been treated by the "scientific" zoology of the last ten years. To this neglect is to be ascribed the fact that modern monographs are almost useless for conscientious zoogeographers, because they treat systematic subjects so superficially, and the reproach, sometimes not entirely without justice, is made against German zoology, that it produces excellent theorizers, distinguished comparative anatomists and embryologists, but no zoologists. As if the knowledge of form were not the basis of all zoology, and as if one could obtain a living conception of the phenomena of variation without having trained the eye by exact systematic studies in at least one group of animals! Darwin himself, at the very time when he was revolving in his mind his undisclosed theory of natural selection, gave in his monograph on the cirripeds,[1] an example of exact systematic description. And what systematic zoologist does not know the important fact that there often exists between apparently unessential external characters and important points of internal organization so profound a correlation that

[1] Charles Darwin, A Monograph of the subclass Cirripedia, with figures of all the species. Two vols., London, 1851–1854.

artificial systems built upon those alone are found to correspond to the grouping according to natural relationships?

It is well known that a change in this policy is required. So the Deutsche Zoologische Gesellschaft resolved, soon after its successful establishment in 1890, to publish an immense, systematic work[1] embracing all the forms of animals known up to this time, and also undertook a new edition of the Systema Naturæ of Linnæus.[2] These are eloquent signs of the necessity for profound systematic work.

Yet it should not be overlooked that the best modern descriptions of species are pure abstractions that seek to embrace in a single specially colored picture the result of the researches made upon a greater or less number of individuals. By a synthesis of this sort we form ideas of species to which no single individual ever exactly corresponds, and which, while they suffice indeed for the prime necessity of lucidity, can never give the materials needed for the scientific construction of the theory of descent. For that purpose there would be required descriptions, as exact and bare as possible, of numerous single objects. It would be necessary to exactly portray the collective examples of several generations with all their individual traits, especially in the case of such species as were considered variable. If the race then encountered different external conditions, it would in this way be possible to separate the constant, inherited characters from the variable ones. In the botanical field there exists, in Nägeli's work on the Hieraceæ, an investigation of this kind which has given to that acute thinker an opportunity to remark on the importance of a sharp distinction between uniformity and constancy, as well as between multiformity and variation.[3] In the animal kingdom, while such experiments are much more difficult, they are certainly not impossible, and yet they are entirely unknown.[4] In this direction there is open to the systematists of the future a great and remunerative field for work.

So we find that systematic zoology, which in the "descriptive" age before Darwin, confined itself to short differential diagnoses and inventories arranged for clearness only, but afterwards took upon itself the office of an ancestral tree, defining true blood relationships, is to become, in the next period of our science, quite indispensable to the experimental method.

[1]The publication of this is fortunately already secured and for most groups of the animal kingdom competent editors have been obtained. It will appear under the title: Das Tierreich. Eine Zusammenstellung und Kennzeichnung der rezenten Tierformen. To be published by R. Friedländer und Sohn in Berlin.

[2]Caroli Linnæi Systema naturæ, regnum animale. Editio decima, 1758. Cura societatis zoologicæ germanicæ iterum edita. Berolini, 1894.

[3]C. v. Nägeli, Mechanisch-physiologische Theorie der Abstammungslehre, page 239 ff. München und Leipzig, 1894.

[4]Even for the most elementary of the questions here considered, that of the degree of variability of animal species in a state of nature, there has been up to the present time but little material collected. Compare A. R. Wallace, Darwinism, authorized translation into German by D. Brauns, Braunschweig, 1891.

On looking back, we see that in all the principal branches of zoological science the theory of descent founded by Darwin has become the leading motive of an investigating activity such as was unknown in any former period.

This activity is characterized by a preponderance of morphological interests which has led to such an unjust neglect of physiology that to-day, when it has become necessary to consider morphological development in order to state problems whose solutions can only be obtained by experiment, neither the working methods nor even the workers are to be found who can solve such problems.

Therefore, morphology, seeking for light, threatened to have recourse to a new edition of Schelling-Oken's Natural Philosophy, since the new way out of the difficulties was not yet staked out by sound experience.

Although controlled by an exclusively morphological tendency opposed to its own proper ends, zoology has begun to recognize as a new branch of work the "causes of organic morphogeny," and Roux has already founded a special journal[1] for it. But this name does not indicate the entire scope of the effort, which would be much better characterized as "comparative physiology" or "biomechanics."[2]

Darwinism has filled the old descriptive zoology with a philosophical spirit, and given it a historical character; it now remains the duty of the coming generation to so shape it that it will become a causal science, resting upon an experimental basis.

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[1] Archiv für Entwickelungsmechanik, edited by W. Roux. Leipzig, 1894, et seq.

[2] Y. Delage. Une science nouvelle: la Biomécanique. (Revue générale des sciences pures et appliquées, 6e année, no. 10, Paris, 1895.

THE EVOLUTION OF MODERN SCIENTIFIC LABORATORIES.[1]

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The scientific discoveries of the present century have had such a profound influence upon inventions, upon industries, and upon the comfort, health, and welfare of the people in general, that there is widespread, even if not always adequate, appreciation of the value of scientific study and investigation. But it may be doubted whether there is any proper understanding, in the minds even of the educated public, of the material circumstances which surround scientific discovery and which make it possible. The average man, if interested at all, is interested that the discovery is made, not how it is made.

In this country, where we must rely mainly upon enlightened private beneficence, and not upon governmental aid, to furnish the pecuniary resources which are essential for scientific progress, it is important that there should be some general information not only regarding the results of scientific work, but also regarding the external material conditions necessary for the fruitful prosecution of such work.

At the present day the systematic study and advancement of any physical or natural science, including the medical sciences, requires trained workers who can give their time to the work, suitably constructed workrooms, an equipment with all of the instruments and appliances needed for the special work, a supply of the material to be studied, and ready access to the more important books and journals containing the special literature of the science.

All of these conditions are supplied by a well-equipped and properly organized modern laboratory. Such laboratories are, with the partial exception of the anatomical laboratory, entirely the creation of the present century, and for the most part of the last fifty years. They have completely revolutionized during the past half century the material conditions under which scientific work is prosecuted. They are partly the result, and in larger part the cause, of that rapid progress

[1] An address delivered at the opening of the William Pepper Laboratory of Clinical Medicine, Philadelphia, December 4, 1895. From the Johns Hopkins Hospital Bulletin, No. 58, January, 1896.

of the physical and natural sciences which characterizes the era in which we are living.

The evolution of the modern laboratory still awaits its historian. It is not difficult to find incidental references to historical facts bearing upon this subject. The development of the chemical laboratory has been traced with some fullness. But it is curious that there is no satisfactory monographic treatment of the general subject of the historical development of scientific laboratories. The subject seems to me an attractive one. It would surely be interesting to trace the development of the teaching and the investigating laboratory back to its beginnings, to learn about the material circumstances under which the physicists, the chemists, the morphologists, and physiologists of former generations worked. What share in the development of laboratories had the learned academies of the Renaissance and of the subsequent centuries? What share had public and private museums and collections of instruments of precision? What share had the work of the exact experimentalists, beginning with Galileo, of physicians, of the alchemists, and of the apothecaries? What individuals, universities, corporations, and governments were the pioneers in the establishment of laboratories for the various physical and natural sciences? The detailed consideration of these and many other questions pertinent to the subject would make an interesting and valuable historical contribution.

There is evidence that in Alexandria, under the early Ptolemies in the third century before Christ, there existed State-supported institutes, in which students of man and of nature could come into direct personal contact with the objects of study, and by the aid of such appliances as were then available could carry on scientific investigations. The practical study of anatomy, physiology, pathology, and other natural sciences was here cultivated. We are very imperfectly informed as to the results and the material circumstances of this remarkable period in the history of science. We know that after about a century of healthy activity the Alexandrian school gradually sank into a place for metaphysical discussions.

Fifteen hundred years elapsed before we next find any record of the practical study of a natural science. In 1231, the great Hohenstaufen, Frederick the Second, who has been called the most remarkable historic figure of the Middle Ages, commanded the teachers at Salernum diligently to cultivate the practical study of anatomy. After the passage of this edict occasional dissections of the human body were made, but it can not be said that there was any diligent cultivation of anatomy on the part either of teachers or of students during the following two centuries.

In the latter half of the fifteenth century there developed that active interest in the practical study of human anatomy which culminated in the immortal work of Vesalius, published in 1543. After this the study

of anatomy by dissections gradually assumed in the medical curriculum that commanding position which it has maintained up to the present day.

For over six hundred years there has been at least some practical instruction in anatomy, and for over three hundred years there have existed anatomical laboratories for purposes of teaching and of investigation, although only those constructed during the present century meet our ideas of what an anatomical laboratory should be. It is a matter of no little interest, both for the history of medicine and for that of science in general, that the first scientific laboratory was the anatomical laboratory. Private laboratories for investigation must have existed from the earliest times. Doubtless Aristotle had his laboratory. But the kind of laboratory which we have on this occasion in mind is one open to students or investigators or both. There was no branch of physical or natural science, with the exception of anatomy, which students could study in the laboratory until after the first quarter of the present century. Only in anatomy could students come into direct contact with the object of study and work with their own hands and investigate what lay below the surface.

The famous Moravian writer on education, Amos Comenius, over two hundred and fifty years ago, gave vigorous expression to the conception of living, objective teaching of the sciences. He said: "Men must be instructed in wisdom so far as possible, not from books, but from the heavens, the earth, the oaks, and the beeches—that is, they must learn and investigate the things themselves, and not merely the observations and testimonies of other persons concerning the things." "Who is there," he cries, "who teaches physics by observation and experiment instead of by reading an Aristotelian or other text-book?" But how little ripe were the conditions then existing for the successful carrying out of ideas so far in advance of his times is illustrated by the very writings of the author of "Orbis Pictus" and "Lux in Tenebris."

It would lead too far afield to trace, in detail, on this occasion, the development of physical and of chemical laboratories, but on account of the intimate connection between the development of physics and chemistry and that of medicine, especially of more exact experimental work in the medical sciences, a few words on this subject will not be out of place.

Methodical experimentation in the sciences of nature was definitely established by Galileo, and was zealously practiced by his contemporaries and successors in the seventeenth century. It was greatly promoted by the foundation, during this century, of learned societies, such as the Accademia dei Lincei and the Accademia del Cimento, in Italy, the Collegium Curiosum, in Germany; the Académie des Sciences, in Paris, and the Royal Society, in England. Much of the classical apparatus still employed in physical experiments was invented at this

period. Experimental physics from the first acquired a kind of fashionable vogue, and this aristocratic position it has ever since maintained among the experimental sciences. These sciences must concede to physics that commanding position which it has won by the genius of the great natural philosophers, by the precision of its methods, and the mathematical accuracy of its conclusions, and by the fundamental nature and profound interest and importance of its problems. The debt of the medical sciences to the great experimental physicists, from Kepler and Galileo and Newton down to Helmholtz, is a very large one, larger than is probably appreciated by medical men who have not interested themselves in the history of experimental and precise methods in medicine.

There existed in the last century cabinets of physical apparatus to be used in demonstrative lectures, but they were very inadequate, and suitable rooms for experimental work scarcely existed. It was not until about the middle of the present century that we find the beginnings of the modern physical laboratory. Lord Kelvin, then William Thomson, established a physical laboratory in the University of Glasgow about 1845 in an old wine cellar of a house. He tells us that "this, with the bins swept away and a water supply and sink added, served as a physical laboratory for several years." It was as late as 1863 that Magnus opened in Berlin his laboratory for experimental physical research. Since 1870 there has been a rapid development of those splendid physical institutes which are the pride of many universities.

Humbler, but more picturesque, was the origin of the chemical laboratory. This was the laboratory of the alchemist searching for the philosopher's stone. In the painter's canvas we can still see the vaulted, cobwebbed room, with its dim and mysterious light, the stuffed serpent, the shelves with their many-colored bottles, the furnace in the corner with the fire glowing through the loose bricks, the fantastic alembics, the old alchemist in his quaint armchair reading a huge, worm-eaten folio, and the assistant grinding at the mortar. Fantastic and futile as it all may seem, yet here was the birth of modern chemistry. The alchemists were the first to undertake the methodical experimental investigation of the chemical nature of substances. No more powerful stimulus than the idea of the philosopher's stone could have been devised to impel men to ardent investigation. But search for gold was not all that inspired the later alchemists. Paracelsus, the alchemist, that strange but true prophet of modern medicine as he was of modern chemistry, said, "Away with these false disciples who hold that this divine science, which they dishonor and prostitute, has no other end but that of making gold and silver. True alchemy has but one aim and object, to extract the quintessence of things, and to prepare arcana, tinctures, and elixirs which may restore to man the health and soundness he has lost." And again he says of the alchemists, "They are not given to idleness nor go in a proud habit or plush or

velvet garments, often showing their rings upon their fingers, or wearing swords with silver hilts by their sides, or fine and gay gloves upon their hands, but diligently follow their labors, sweating whole days and nights by their furnaces. They do not spend their time abroad for recreation, but take delight in their laboratory. They wear leather garments with a pouch and an apron wherewith to wipe their hands. They put their fingers among coals and into clay, not into gold rings."

During the seventeenth and eighteenth centuries the doctrines and work of the alchemists had profound influence upon medicine. Alchemy was not completely overthrown until Lavoisier gave the deathblow to the phlogistic theory of Stahl. But for a considerable time before Lavoisier introduced the new spirit into chemistry its methods and its problems were gradually approaching those of modern times. It was, however, over thirty years after the tragic death of Lavoisier before the first chemical laboratory in the modern sense was established. One can not read without combined feelings of wonder and pity of the incommodious, forlorn, and cramped rooms in which such men as Scheele and Berzelius and Gay Lussac worked out their memorable discoveries. Liebig has graphically described the difficulties encountered by the student of that day who wished to acquire practical training in chemistry. With some of the apothecaries could be obtained a modicum of practical familiarity with ordinary chemical manipulations, but Sweden and France were the centers for those with higher aspirations.

It was the memory of his own experiences which led Liebig, immediately after he was appointed professor of chemistry in Giessen in 1824, to set about the establishment of a chemical laboratory. Liebig's laboratory, opened to students and investigators in 1825, is generally stated to be the first modern public scientific laboratory. Although, as we shall see presently, this is not quite correct, it is certain that Liebig's laboratory was the one which had the greatest influence upon the subsequent establishment and organization not only of chemical laboratories, but of public scientific laboratories in general. Its foundation marks an epoch in the history of science and of scientific education. This laboratory proved to be of great import to medical science, for it was here, and by Liebig, that the foundations of modern physiological chemistry were laid.

The significance of this memorable laboratory of Liebig is not that it was a beautiful or commodious or well-equipped laboratory, for it possessed none of these attributes—indeed, it is said to have looked like an old stable, but that here was a place provided with the needed facilities and under competent direction, freely open to properly prepared students and investigators for experimental work in science.

The chemical laboratories of to-day are, in general, the best organized and the best supported of scientific laboratories.

The need of establishing physiological laboratories was recognized several years before the foundation of Liebig's laboratory. The

important results to be derived from the application of the experimental method to the study of vital phenomena had been demonstrated first, and most signally, by Harvey, and after him by many experimenters. The fecundity of exact experimentation by physical and chemical methods applied to the phenomena of life had been shown by the classical researches of Lavoisier on respiration and animal heat. Magendie had entered upon that remarkable scientific career which entitles him to be regarded as the founder of modern experimental physiology, pathology, and pharmacology.

In 1812, Gruithuisen, who, after the custom of the times, filled an encyclopedic chair, being professor in Munich of physics, chemistry, zootomy, anthropology, and later of astronomy, published an article advocating the establishment of physiological institutes. In 1823, Purkinje, one of the most distinguished physiologists of this century, accepted the professorship of physiology in Breslau, this being the first independent chair of physiology in any German university. In 1824, Purkinje succeeded in establishing a physiological laboratory, which therefore antedates by one year Liebig's chemical laboratory in Giessen, although it can not be said to have exercised so great an influence upon the organization of scientific laboratories in general as did the latter. In 1840, Purkinje obtained a separate building for his laboratory.

With two or three exceptions, all of the separate physiological laboratories worthy of the name have been established since the middle of the present century. Bernard, that prince of experimenters, worked in a damp, small cellar, one of those wretched Parisian substitutes for a laboratory which he has called "the tombs of scientific investigators." There can be no greater proof of the genius of Bernard than the fact that he was able to make his marvelous discoveries under such obstacles and with such meager appliances. France was long in supplying her scientific men with adequate laboratory facilities, but no more unbiased recognition of the value and significance of the German laboratory system can be found than in the reports of Lorain, in 1868, and of Wurtz, in 1870, based upon personal study of the construction and organization of German laboratories.

Of modern physiological laboratories, the one which has exerted the greatest and most fruitful influence is unquestionably that of the late Professor Ludwig in Leipzig. This unequaled position it has won by the general plan of its organization, its admirable equipment, the number and importance of the discoveries there made, its development of exact methods of experimentation, the personal character and genius of its director, and the number of experimenters there trained from all parts of the civilized world.

To-day every properly equipped medical school has its physiological laboratory. This department is likely to continue to hold its place as the best representative of exact experimental work in any medical science. A good knowledge of physiology is the best corrective of pseudoscientific, irrational theories and practice in medicine.

Physiological chemistry has been an important department of research for over half a century, but it is only within recent years that there have been established independent laboratories for physiological chemistry. A large part of the work in this branch of science has been done hitherto in laboratories of general chemistry, of physiology, of pathology, and of clinical medicine. A physiological laboratory can not well be without a chemical department, and the same is true of several other medical laboratories; but it seems to me that physiological chemistry has won its position as an independent science, and will be most fruitfully cultivated by those who with the requisite chemical and biological training devote their entire time to it. The usefulness of independent laboratories for physiological chemistry has been shown by the work done in Hoppe-Seyler's laboratory in Strassburg since its foundation in 1872. This was the first independent laboratory of physiological chemistry.

The first pathological laboratory was established by Virchow, in Berlin, in 1856. About this time he wrote: "As in the seventeenth century anatomical theaters, in the eighteenth clinics, in the first half of the nineteenth physiological institutes, so now the time has come to call into existence pathological institutes, and to make them as accessible as possible to all." It can not be doubted that the time was fully ripe for this new addition to medical laboratories. Virchow secured his laboratory as a concession from the Prussian Government upon his return from Wurzburg to Berlin. Virchow's laboratory has been the model as regards general plan of organization for nearly all pathological laboratories subsequently constructed in Germany and in other countries. It embraced opportunities for work in pathological anatomy, experimental pathology, and physiological and pathological chemistry. This broad conception of pathology and of the scope of the pathological laboratory as including the study not only of diseased structure, but also of disordered function, and as employing the methods not only of observation, but also of experiment, should never be lost sight of.

The first to formulate distinctly the conception of pharmacology as an experimental science distinct from therapeutics and closely allied by its methods of work and by many of its problems to physiology was Rudolph Buchheim. This he did soon after going to Dorpat, in 1846, as extraordinary professor of materia medica, and it was apparently not long after he there became ordinarius, in 1849, that he established a pharmacological laboratory in his own house and by his private means. Later, this laboratory became a department of the university and developed most fruitful activity. Buchheim's laboratory was the first pharmacological laboratory in the present acceptation of this term. The conception of pharmacology advocated by Buchheim has been adopted in all German universities, and in not a few other universities; but it can not be said to have been as yet generally accepted in the

medical schools of this country and of Great Britain, although it seems destined to prevail.

The medical science which was the latest to find domicile in its own independent laboratory is hygiene. To Pettenkofer belongs the credit of first establishing such a laboratory. Since 1847 he had been engaged with hygienic investigations, and in 1872 he secured from the Bavarian Government the concession of a hygienic institute. This admirably equipped laboratory was opened for students and investigators in 1878. By this time Koch had already begun those epochal researches which, added to the discoveries of Pasteur, have introduced a new era in medicine. The introduction by Koch of new methods of investigating infectious diseases and many hygienic problems became the greatest possible stimulus for the foundation of laboratories of hygiene and bacteriology, and to some extent also of laboratories of pathology. The results already achieved by these new methods and discoveries in the direction of prevention and cure of disease, and the expectation of no less important results in the future, constitute to-day our strongest grounds of appeal to governments and hospitals and medical schools and the general public for the establishment and support of laboratories where the nature, the causes, the prevention, and the cure of disease shall be investigated. You have established here, in this city, and in connection with this university, the first hygienic laboratory of this country, housed in its own building and assured, I believe, of a future of great usefulness.

It is apparent, from the brief and imperfect outline which I have presented of the evolution of modern scientific laboratories, that the birthplace of these laboratories, regarded as places freely open for instruction and research in the natural sciences, was Germany. Such laboratories are the glory to-day of German universities, which possess over two hundred of them. By their aid Germany has secured since the middle of the present century the palm for scientific education and discovery.

Great scientific investigators are not limited to any country or any time. There are those of surpassing ability who will make their own opportunity and will triumph over the most discouraging environment. This country and every civilized country can point to such men, but they are most exceptional. The great majority of those even with the capacity for scientific work need encouragement and opportunity. We now have sufficient knowledge of the workings of scientific laboratories to be able to assert that in general where the laboratory facilities are the most ample and the most freely available, there are developed the largest number of trained workers, and there the discoveries are the most numerous and the most important. At the present day no country, no university, and no medical school can hold even a respectable place in the march of education and progress unless it is provided with suitable laboratories for scientific work.

A properly equipped and properly conducted scientific laboratory is a far more expensive institution than is usually conceived. It must be suitably domiciled either in a separate building or in rooms commodious and well lighted. The outside architectural features are of secondary importance. The instruments and appliances necessary for exact observation and experiment, even in those sciences which apparently require the least, are numerous and costly. A working library, containing the books and sets of journals most frequently consulted, is most desirable, if not absolutely indispensable. The director of the laboratory should be a man of ability and experience, who is a master in his department of science. He must have at least one assistant, who is preferably a young man aiming to follow a scientific career. A person of no small value in the successful working of the laboratory is the intelligent janitor or "diener," who can be trained to do the work of a subsidiary assistant and can be intrusted with the care and manipulation of instruments. There must be funds for the purchase of fresh supplies and new instruments when needed. The running expenses of a first-class laboratory are not small.

But costly as may seem the establishment and support of a good laboratory, the amount of money expended for laboratories would seem to us ridiculously insignificant if we could estimate the benefits to mankind derived from the work which has been done in them. Wurtz has truly said of the money required for laboratories, "It is a capital placed at a high rate of interest, and the comparatively slight sacrifice imposed upon one generation will bring to following generations increase of well-being and knowledge."

The educational value of the laboratory can not well be overestimated. For the general student this is to be found primarily in the development of the scientific habit of thought. He learns that to really know about things it is necessary to come into direct contact with them and study them. He finds that only this knowledge is real and living, and not that which comes from mere observation of external appearances, or from reading or being told about things, or, still less, merely thinking about them.

The problem of securing for the student of medicine the full benefits of laboratory instruction in the various medical sciences is a difficult one, and can not, I believe, be solved without considerable readjustment of existing schemes of medical teaching; but this subject is one which I can not attempt to consider here.

The whole face of medicine has been changed during the last half century by the work of the various laboratories devoted to the medical sciences. Anatomy, physiology, and pathology now rank among the most important of the sciences of nature. They have been enriched with discoveries of the highest significance and value not only for medicine, but also for general biology. Although we have not penetrated, and perhaps may never penetrate, the mystery of life,

we are coming closer and closer to an understanding of the intimate structure and the fundamental properties of living matter. We already know that living matter is not that homogeneous, formless substance which not many years ago it was believed to be, but that it possesses a complex organization.

Practical medicine has been profoundly influenced by the unparalleled development of the medical sciences during the last fifty years, and especially during more recent years. Scientific methods have passed from the laboratory to the hospital. Cases of disease are now studied with the aid of physical and chemical and microscopical and bacteriological methods. The diagnosis of disease has thereby been greatly advanced in precision, and if Boerhaave's motto, "qui bene diagnoscit, bene medebitur," be true, there should be a corresponding advance in the results of the treatment of disease. Whether or not this dictum of the old master be true—and I have serious doubts as to its entire truth—it can not be doubted that great progress has been made in medical, and especially in surgical, treatment as a result of scientific discoveries, although the treatment of disease still rests, and will doubtless long continue to rest, largely upon empirical foundations.

We are assembled here to-day to assist at the opening of a laboratory which gives the fittest and strongest possible expression to the influence of scientific work upon practical medicine. The generous founder has marked with characteristic insight the direction in which the current is setting.

The conception of a thoroughly equipped laboratory as an integral part of a hospital and intended for the study and investigation of disease is of recent origin. The germs of this idea, however, may be traced back to such men as Hughes Bennett and Beale in Great Britain, and to Frerichs and Traube in Germany, who in their hospital work made fruitful application of microscopical, chemical, and experimental methods. A little over ten years ago, Von Ziemssen, in Munich, established a well-conceived clinical laboratory, containing a chemical, a physical, and a bacteriological department, a working library, and rooms for practical courses and the examination of patients. A similar laboratory was secured by Curschmann in Leipzig in 1892.

The growing recognition of the need of such laboratories is the result of the great progress in scientific medicine during recent years. The thorough clinical examination of many cases of disease now requires familiarity with numerous technical procedures, physical, chemical, microscopical, and bacteriological. The laboratory outfit required simply for routine clinical examinations is considerable. A microscope and a few test tubes and chemical reagents for simple tests of the urine no longer suffice. As illustrations of this, I call attention to the clinical value of examinations of the blood, of the contents of the stomach, of fluids withdrawn from the serous cavities, of the sputum and various secretions, of fragments of tissue removed for diagnosis. Such

examinations require much time, trained observers, and considerable apparatus. To secure for the patients the benefits in the way of diagnosis, prognosis, and treatment to be derived from these methods of examination, a hospital should be supplied with the requisite facilities.

A hospital, and especially one connected with a medical school, should serve not only for the treatment of patients, but also for the promotion of knowledge. Where this second function is prominent, there also is the first most efficiently and intelligently carried out. Herein we see the far-reaching beneficence of a laboratory, such as this one, thoroughly equipped to investigate the many problems which relate to clinical medicine.

The usefulness of an investigating laboratory in close connection with a hospital has already been abundantly demonstrated. Chemical studies, more particularly those relating to metabolism in various acute and chronic affections, microscopical and chemical investigations of the blood and bacteriological examinations of material derived directly from the patient, may be mentioned as directions in which researches conducted in hospital laboratories have yielded important results and will garner still richer harvests in the future.

There need be no conflict between the work of clinical laboratories and that of the various other medical laboratories. Each has its own special field, but it is not necessary or desirable to draw around these fields sharp boundary lines beyond which there shall be no poaching. It will be a relief to pathological and other laboratories to have certain examinations and subjects relating directly to practical medicine consigned to the clinical laboratory, where they can receive fuller and more satisfactory consideration. The subject-matter for study in the clinical laboratory is primarily the patient and material derived from the patient. Anatomical, physiological, pathological, pharmacological, and hygienic laboratories must concern themselves with many problems which have apparently no immediate and direct bearing upon practical medicine. In the long run, their contributions are likely to prove most beneficial to medicine if broad biological points of view, rather than immediate practical utility, are their guiding stars. The clinical laboratory will concern itself more particularly with questions which bear directly upon the diagnosis and the treatment of disease.

To the small number of existing well-equipped clinical laboratories the William Pepper Laboratory of Clinical Medicine is a most notable addition. It is the first laboratory of the kind provided with its own building and amply equipped for research in this country, and it is not surpassed in these respects by any in foreign countries. It is intended especially for investigation and the training of advanced students. It is a most worthy memorial of the father of its founder.

William Pepper, the elder, was a very distinguished physician and trusted consultant of this city, for many years an attending physician at the Pennsylvania Hospital, where he was a clinical teacher of great

influence, and for four years the professor of the theory and practice of medicine in this university. He belonged to that remarkable group of American physicians, trained under Louis, who brought to this country the best methods and traditions of the French school of medicine at the time of its highest glory. His diagnostic powers are said to have been remarkable. With his broad sympathies, his lofty ideals, and his active and enlightened efforts for the promotion of clinical medicine, how he would have welcomed such opportunities as will be afforded by this laboratory to contribute to a better knowledge of the nature, the diagnosis, and the treatment of disease.

Our country has, until within a very few years, been deprived of the encouragement and opportunities for original investigations in the medical sciences afforded by large and thoroughly equipped laboratories. We can still count upon the fingers of one hand our medical laboratories which are comparable in their construction, organization, and appliances to the great European laboratories. Notwithstanding these obstacles, there have been American physicians of whose contributions to medical science we may feel proud.

But a new era has dawned. Of that we are witnesses here to-day. The value of medical laboratories is now widely recognized among us. To those of us who appreciate the underlying currents in medicine, who follow with eager interest the results of the almost feverish activities in foreign laboratories, who recognize the profound interest and importance of the many medical problems which await only patient investigation and suitable facilities for their solution, and who would like to see our country take the prominent position it should in these investigations, our laboratories may seem slow in coming, but they will in time be provided by enlighted benevolence. The individual or institution or hospital which contributes to the establishment of a good laboratory devoted to any of the medical sciences merits in unusual degree the gratitude of all medical men; yes, of every true friend of humanity. Such gratitude we feel for the generous and public-spirited founder of this laboratory, who has contributed largely to the advancement of medicine in this country, and of whose splendid services to this university I need not speak in this presence.

I congratulate this city and this university and this hospital upon the important addition made by this laboratory to higher medical education and the opportunities for scientific work in this country. May the enlightened aims of the founder and the hopes of all interested in the promotion of medicine in this country be fulfilled by the scientific activities which will now begin in the William Pepper Laboratory of Clinical Medicine.

THE YELLOW RACES.[1]

By Dr. E. T. Hamy.

Last year's course was mainly devoted to the study of that large group of peoples which are collectively known by the name of Yellow Races, although their color forms a chromatic scale, which at times is perceptibly removed from what is properly called yellow. This group of races, this main stem (trunk), to borrow a happy expression imported into science by M. de Quatrefages, is, numerically speaking, the most important of all those the great whole of which might be considered as the human forest. In fact, the number of yellow men could not, properly speaking, be estimated at less than 540,000,000; this is more than one-third of the whole number of mankind,[2] and I ought surely not curtail the study of so important a fraction of the human family, although I must acknowledge that the precise facts concerning the yellow races are as yet far from sufficient.

With a very few exceptions, our anatomical data are in fact only isolated documents. Our numerical observations, our special photographs, are few in number, and the conclusions drawn from the examination and the description of such indifferent materials must consequently be looked upon as eminently provisional only.

Such as I had formulated them quite recently, I have been compelled, after many fruitless efforts, to present them to you once more in this course of instruction, where one after the other, and in systematic order, each human group becomes the object of special inquiry, founded above all upon scientific investigation. And I have been very fortunate to find that, on the whole, my conclusions are not opposed by any opinion maintained elsewhere, and that, making full allowance for outward appearances, they still have nothing that could possibly shock the professional Orientalists, who are accustomed to use for the most ordinary purposes only linguistic characters.

The first observation which we have been called upon to make, as we enter into this subject, has reference to the relative antiquity of the

[1] Opening lecture of the course on Anthropology, held at the Museum on March 23, 1895. Translated from L'Anthropologie, 1895, Tome VI, No. 3.

[2] H. Wagner and A. Supan estimate the population of the earth at about 1,480,000,000. (Die Bevölkerung der Erde, VIII, Gotha, 1891, 4to, p. xi.)

yellow races in a widely extended area. There are indeed certain facts which justify us in supposing that one of these ancient, but now extinct races, knew the vanished mammalia of the valley of the Rhone, and that other old Mongolians lived in the east of Europe and in Upper Asia at a certainly less remote, but still very ancient epoch.

Restricted from the beginning to a rather septentrional habitat, the yellow peoples remained unknown to the ancient Egyptians until the time of the invasion of the Shepherd race, certain leaders of whom, depicted on the monuments of Sân or the Fayoum, bear truly Mongolian features. In Mesopotamia they may have furnished the elements of one of the two ethnical groups which in the dawn of history competed for preeminence under the names of *Accad* and *Sumer*. Accad, whose language is akin to the so-called *Turanian* idioms, ruled at Babylon, and displays on the few monuments on which its image is preserved very striking features.

The Mongolian features continue a process of exaggeration on certain more recent figures, where we see, as, for instance, at Behistun, among the prisoners of Darius, genuine Mongols with turned-up noses, delicate mustaches, high and prominent cheek bones, etc. Still other Mongolian faces are represented in the famous ruins of Sanchi (Malva), etc. We must, nevertheless, come down as far as Attila's invasion to collect some fragments of description, in which the Hun may appear with increased horror, owing to the fright with which he had filled the Christian world. Forma brevi, lato pectore, capite grandiori, minutis oculis, barba rara, simo naso, tetro colore, originis suae signa restituens—thus writes Jordanes, describing Attila himself.

Many other historians, both Eastern and Western, have since that time depicted the immigrant hordes who passed through the breaches made by the Huns and opened for themselves a road to the very heart of the Empire: Avars, Chazars, Komans, and those Hungarians and Bulgarians, the fathers of the ogres of our legends, the bugaboos of popular speech. None of these portaits is more striking than that which is inserted by Mathieu Paris in his Grande Chronique. The clerk Yvon, of Narbonne, wrote from Neustadt, in 1243, to Girauld, archbishop of Bordeaux, to inform him of the devastations of the barbarians, and thus described these invaders, who became ever after known under the name of Tartars:

"Their breast," he says, "is solid and robust, *habent autem pectora dura et robusta;* their face is lean and pale, *facies macras et pallidas;* their shoulders are straight and high, *scapulas rigidas et erectas;* a short and turned-up nose, *nasos distortos et breves;* the chin is prominent and pointed, *menta prominentia et acuta;* the upper jaw is low and deep, *superiorem mandibulum humilem et profundum;* their teeth are long and few, *dentes longos et raros;* the eyelids hang from the eyebrows down to the nose, *palpebras a crinibus usque ad nasum protensas;* their eyes are mobile and black, *oculos inconstantes et nigros;* their look is a sideway and fierce look, *aspectus obliquos et torros;* their extremities are all bone and nerve, *extremitates ossosas et nervosas;* finally, their thighs

are big, but the legs short; in stature, however, they are our equals, for what may be wanting in the legs is made up in the upper part of the body, *crura quoque grossa, sed tibias breviores, statura tamen nobis æquales: quod enim in tibiis deficit id in superiore corpore compensatur.*"[1]

This portrait of the Tartar, drawn by Yvon, of Narbonne, is very remarkable in spite of its exaggerations and mistakes.

It shows, in fact, how the attention of the observer was at that time called to some of the principal features of that exceptional morphology which make of the true Mongol one of the fundamental anthropological types. From that time on Europeans, missionaries, merchants, etc., who shall approach the mysterious countries of the East will collect impressions less and less limited, less and less vague. And if in their reports they still continue to confound in one and the same great body races which have since been found to be infinitely varied, they will at least gradually establish a kind of general grouping, a first essay at coordination, which later on will lead to a rational classification.

Bernier is a fair representative of this phase of Asiatic studies in his famous letter, "On the different varieties of races of men," inserted in the Journal des Savants of 1684. "The third variety," he says, after having spoken of the whites and blacks, "the third variety comprehends a part of the kingdoms of Arakan and of Siam, of the islands of Sumatra and Borneo, the Philippines, Japan, the Kingdom of Pegu, Tonquin, China, Cochinchina, Tartary, which lies between China, the Ganges and Moscovia, Usbeg, Turkistan, Zaquetay, a part of Moscovia, the Little Tartars and the Turkomans, who live on the banks of the Euphrates toward Aleppo." "The inhabitants of all these countries," adds the illustrious traveler, "are really whites, but they have broad shoulders, flat faces, a small, crushed nose, small pig eyes, long and deep sunk, and three hairs for a beard."

This third variety of men of Bernier's is almost exactly the yellow trunk of modern anthropologists. The Americans alone are wanting, because Bernier with his imperfect knowledge of them did not see in them a sufficiently great difference to warrant making of them a special variety that would differ from ours. Mongols and Turks, Indo-Chinese, Japanese, and Malays are here all of them put into one and the same mold, which is to be broken up only much later by ethnologists, linguists, and anthropologists.

The names of Pallas, Castréro, Baër, and many others recall the vigorous efforts made for more than a century now to introduce a little order into Mongolic studies. The linguists insist upon it that we should not mix up in one and the same great whole people who speak monosyllabic languages and others who use the agglutinative system. The ethnologists also find it easy to show clearly the profound divergences which result from entirely different social systems, as from entirely

[1] Mathæi Parisiensis, monachi Sancti Albani, Chronica major, edit, by R. Luard, Vol. IV, 1877, in 8vo.

different moral codes. The anthropologists finally claim the great importance of physical characteristics which are now studied for this purpose, with the aid of exact instruments, applied to living subjects as well as to skeletons. And from the coordination of all these combined studies there results a classification, which no doubt will yet have to undergo important changes, but which already, and however insufficient it may remain as yet, may give to instruction on this subject the frame work, so to say, which it needs, even though it be only provisional.

It is no longer sufficient, in fact, as it was for Buffon, to compile the reports of travelers and to put them side by side in geographical order. Now, those descriptions which have become more accurate and more scientific must be presented in the most logical connection that is possible, and the characteristic features must appear subordinated in natural succession. It is only by applying these principles that we have succeeded in combining a classification which, before going any further, we deem it proper to present here in a summary arrangement.

Let us first of all recall the fact that we began by putting aside provisionally the American and the Malayan races, for a complete study of which this year's course will hardly suffice. Having thus gained more space for our purposes, we have set aside eight fairly kindred subjects, which are more or less voluminous, more or less ramified, which we will for the present mention by the names of Mongol, Turk, Indo-Mongol, Aleut, Tungus, Aino, Chinese, and Eskimauan.

The first is the properly so-called Mongolian branch, which has occasionally, by a mistake, given its name to the whole family, and which, on account of the exaggerations of all kinds that flourish concerning the subdivisions of which it consists, well deserves to occupy the first place at the head of our group. The word which designates it (Mongkou), and which means brave, bold, generous, is, however, the name of that fraction of the Chi-houéï to which Gengis Khan belonged, which sufficiently explains the part that such a name has played and still plays in the nomenclature of races.

The Mongolians constitute a mass of 2,000,000 to 3,000,000 souls almost all of whom dwell between Siberia and China, Manchuria and Turkestan; they are actually subdivived into Eastern Mongolians, the most numerous of whom, the Khalkas, are sometimes called Exterior Mongolians (the Interior Mongolians form the tribes Chakhan, Ourote, Ordo, etc.); Western Mongolians, called Kalmuks by the Turks, and subdivided into Songares or Tchoroses, Derbethes, Torgotes or Targoutes, and Khochotes or Khochooutes of the Ala-Chan, and finally Bouriats, sometimes called Northeastern Mongolians.

To whichever group they may belong, these Mongolians are, as I have said before, the most marked of all yellow men; they exaggerate all their characteristic features to such a degree that in endeavoring to sketch the points that specially distinguish them, we have been able to form, as it were, a kind of large canvass, on which, afterwards, all our other Asiatic designs could be fitted, one after the other.

We have at the very first microscopically examined their hair, the most liotrichian that can be found, circular in form, at the same time very coarse, very black, very stiff, and very hard. We have analyzed the elements of that only slightly pigmented skin in its shades varying from citrine white to yellowish or reddish brown. We have next tried to explain to ourselves the morphology of those so-called bridled eyelids which are so characteristic of the race, and we have found, with Siebold, that they owe their peculiar aspect to a cutaneous fold which masks the corner of the eye until it makes the lacrymal caruncle invisible and covers the inner third of the tarsus cartilage, and to a thickening of the same cartilage under the upper eyelid, which covers and half hides the lashes. The opening of an eye thus "bridled" is curtailed, triangular, and often even oblique. We have found that these peculiar appearances of the Mongolian eye are independent of the facial skeleton, since there are in existence very many Asiatic subjects—I have exhibited several to you—in whom a nose of very great elevation and cheek bones very closely resembling our own may coexist with the most strikingly deformed eyes that could possibly be found in Mongolian countries.

The study of the skeleton has shown us that the Mongolian skull is hyperbrachycephalous; its cephalic index exceeds 87; it is a genuine Mongolian skull, which, for the present, represents the extreme limit of brachycephalism, free from deformity, with the index 98, 21 (Huxley). Shortened, enlarged, and at the same time elliptical, it is perceptibly less high than broad, and well deserves the name of platy brachycephalous, which I have recently bestowed upon it.[1] The face is in perfect harmony with this low skull, expanded transversely; it looks like a more or less shortened lozenge. The external orbital apophyses, long and divergent, form a connection with cheek bones of coarse nature, with angular cheeks pressed back on the outside by upper maxillaries of an exaggerated size. Turned down, forward and outward, these cheek bones, at the same time that they bend in a right angle upon their upper and inner edge so as to give to the orbit its remarkable breadth, overreach below in a characteristic projection on which Pruner-Bey has often very justly insisted. This is what he called the daylight orbit (orbite à jour); a part of the orbitary edge becomes really visible in the vertical direction. The Mongolian skull is, moreover, generally phœnozygous; in other words, seen from above it shows its zygomatic arch more or less removed and convex. The maxillaries, which are transversely flattened, become rather hollow at a level with the canine cavities and afterwards develop largely, both transversely and upward. The nasal orifice, which they surround, is quite large, but at the same time very much elongated, and the indication which a comparison of these two dimensions gives is platyrrhinian. The bones of the nose, properly speaking, rise in a prominent ridge, and thus trace in the very center of the facial lozenge a quite characteristic relievo.

[1] Crania Ethnica, p. 402 and foll.

The dental arch is hardly prognathous, below the nasal aperture, to which it frequently adheres in an oblique slope which dispenses with the sharp edge of the prenasal vestibule. This arch is, however, large, short, almost semicircular, and is armed with teeth which present nothing remarkable, neither as to size nor as to shape.

The rather low, very powerful mandible is remarkable for the angular aspect of its symphysis, and of its posterior angles, which are prominent, often extroversated, and which extend on either side in a kind of voluminous heel.

To assist me in this description, I have placed before you some very striking specimens recently brought home from Mongolia by Dr. Ernest Martin, and by placing by the side of these skulls from Eul She Sou Go, some Turkish, Annamite, Chinese skulls, and others, I have given you from the beginning of my demonstration a very precise impression of the large polymorphism of these races, which, though so varied among themselves, are habitually confounded in a veritable amalgam.

All the other characteristic features peculiar to the Mongolians have been examined with the same attention as the anatomical features. In this summary I shall not return to what I have told you at that time of their intellectual and moral nor of their social and religious peculiarities. Availing myself of the descriptions given by the best indorsed writers, I have endeavored to show you the most perfect picture of the life on the steppes, and certain photographs, with a visit to the Guimet Museum, have fortunately come to the assistance of my very unsatisfactory descriptions.

What I have thus done for the true Mongolians, I have next done for the Kalmuks, assisted by a good monograph by M. Deniker for the Bouriats, with the aid of divers documents collected by Messrs. Malieff and Bogdanoff, and we have thus been enabled to recognize how this last race of men, who of all Mongolians assimilated most easily, have in our day most essentially changed in consequence of their repeated alliances with their masters, our friends the Russians.

The second branch which we had to examine was that of the Old Turks, very much nearer to the source from which the Mongolians sprang than they have remained since, but one branch of whom, separated from the others by the great invasions toward the close of the Middle Ages, has in part preserved their archaic aspect. These Northern Turks are the Yakuts, permanently settled to the number of 200,000 souls, as this map shows, on the banks of the lower Lena, and they show us in several tribes, especially in those called Utsha, Cheta, etc., to judge by Middendorf's arguments, very striking Mongolian affinities.

The other Turks (perhaps 20,000,000 souls), those whom we call Turkomans in our works on history, and whose daring invasions into Europe and into Africa have wondrously enlarged their original domain, are

much more mixed, and it is only from the countries whence they drew their historic origin that we can learn something of their character. With Baron de Bode and Colonel Duhousset we have visited them south of the Caspian Sea, under the name of Yamouds, Goklanes, etc., in the Caucasus under the name of Abreks, and we have been able to ascertain that the few practical observations made among these tribes coincide very exactly with those suggested by the Yakuts, their northern near relatives. In examining the skulls of the Turkomans, it becomes, however, necessary to bear in mind that certain of their tribes, and especially the Kurds and the Bakhtyaris have a peculiar custom; they deform the head by exaggerating the parieto-occipital flattening which is common to all Turks, a kind of natural curtailment, which almost constantly presses the top of the skull into a point behind.

This very habitual and very visible distinctive feature at once enables us to establish between the Turks and the Mongolians an immediately perceptible difference. There exists a second that is still more striking, and which, combined with the first, gives to the skull capsule of the Turk, whether he be a Yakut or a Turkoman, a cuboid aspect. This is the tendency of the head to develop upward, consequently just in the opposite sense to the vertical flattening of the Mongolian.

The Turk's head is, therefore, both taller and shorter; it is also a little less large in proportion, and the cephalic index is only subbrachycephalous. The face, adapting itself as is natural to the skull, which is thus slightly curtailed, is less open; on the other hand, the nasal skeleton is even more pronounced in the Turk than in the Mongolian, and you have been able to notice in some Ansariehs, for example, truly amazing instances of large noses.

Before leaving the Turkish branch, we had to examine long lines of types lying intermediate between the Turks and the Mongolians, such as the Uzbeks, the Kirghiz, the Bashkirs, the Nogaïs; between the Turks and the Finns, such as those extremely mixed subjects of the governments of eastern Russia, whom the reports of travelers erroneously designate without distinction as Tartars; finally, between the Turks and the Caucasians, the Slavs, the Greeks, even the Arabs, the Osmanlis of Constantinople, Kourouglis of Algiers, etc. We proceeded from one race to the other by insensible transitions, and we were thus able to appreciate the extreme difficulty which continually confronts us in separating scientifically the yellow men from the white men. We should meet with the same embarrassment if we went farther north in the course of similar inquiries. The lowlands of western Siberia are in the higher northern latitudes overrun by races like the Samoyedes, Kanirs, and others, among whom the individual varieties are really very extensive, and lead, almost without a break, from the Mongolian to the Lapp. Elsewhere in the same zones intermediate types produce other almost imperceptible transitions from the Lapp to the Finn, and from the Finn to the Slav. We are thus able to establish unbroken lines of observation

between the most exaggerated of the yellow men and certain unmistakable white men. It is these transitional populations, if I may call them so, which Prichard, in his desire to designate them by a single collective name foreign to that great western body which he calls Indo-European, had proposed "for the present" to call Allophylian races. Thus he would have fused together, under a perfectly vague appellation, groups as thoroughly distinct, for example, as the Basque, the Finns, the Tschudes, the Ugrians, the Samoyedes, the Ostiaks, and all those East Siberians collectively known under the name of Paralians, etc., a kind of enormous rising en masse of the incerta sedis of the Old World ethnology. These Allophylians of Prichard, however provisionally only the famous author of the Physical History of Mankind may have wished to introduce them, have not yet entirely disappeared from the language of anthropology. Some special writers have retained them faithfully. It can, however, easily be seen that they are losing ground every day, and in some of last year's lectures you may have noticed that careful studies methodically pursued have perceptibly diminished the geographical area of populations which till then had been relegated into the *caput mortuum* of ethnological analysis, because they were not known at all or only very vaguely known.

But let us return to the series already classified, and having got rid of Mongolians and Turks, let us pass on to the races of the Himalaya, their southern and southeastern neighbors, grouped by Prichard under the name of Indo-Tartars, and whom, on account of their geographical position and of their affinities, we think it would be more proper to call Indo-Mongolians.

As far as scattered and incomplete observations will permit us to judge, these people are in almost every aspect intermediate between Turko-Mongolians and Indo-Chinese. In Tibet, where they call themselves Bhôt, they show themselves to be near akin to the Mongolians, with their high cheek bones, "bridled" eyes, and straight noses, which are sometimes even convex, and in certain individuals sufficiently developed to remind us of the redskins of the prairies of the American Plains of the Great West. Their skull is subbrachycephalous. This type, very sharply marked on the high table-lands, gradually becomes less decided as we descend into the lowlands. The crossings, which gradually absorb it, are, moreover, of a greatly mixed nature, borrowing here even from a more or less white race, and there from Dravidians or Kolarians. In Assam, especially, our Indo-Mongolians have contracted alliances with certain tribes of mountaineers, of whom we shall have to say more after the first lectures of this year's course—men who are very marked representatives of the Indonesian element, and who will furnish the subject of our first studies in the ethnology of the Malayan races.

In Indo-China, as at the foot of the Himalaya, there are here and there in the most elevated parts of the country small agglomerations of

evidently Indonesian origin. There are here also, but in vastly larger numbers in Cambodia and the Tsiampa, descendants of ancient Hindoo immigrants. Finally, there exist, especially in the south, a few small tribes of Negritos.

All the remaining population, Birmans, Thaïs or Siamese, Annamites, is bound up with that of Upper Asia, of which we have spoken before, so that they all form a tolerably homogeneous totality, which approaches the Tibetan very nearly. This Indo-Chinese type, subbrachycephalous like the Tibetan, is subdivided into Burmah or Birman, Thaï, and Annamite. We have studied these three groups, one after the other, and we have followed their progress downward from the mountains to the deltas of the rivers, the basins of which they now occupy. A primitive, fairly homogeneous population, of which we shall have to speak again presently, at first occupied these lowlands; these people had, however, to give up the parts adjoining the great water courses to invaders of a different origin, who have gradually reached the south.

Some of these imported into the Eastern Peninsula elements of a civilization which was evidently borrowed from India. I have endeavored to present to you as complete a history of it as was possible, and we have studied together with the greatest carefulness the admirable monuments of their power and their art which they have left us in Cambodia and the Tsiampa. Others were those Burmans, those Thaïs, (Siamese, Laotians), those Annamites, whose fierce conflicts with Tsiampa and Cambodia we have followed from the beginning of this bloody quarrel to the French occupation, which has saved the last remnant of the Khmer people from utter destruction. I paid special attention to the study of those ethnical elements that are peculiar to the lands which we possess in the extreme East; and the examination of the characteristic features of all kinds, which are noticed among the former and the present inhabitants of the lowlands of the Me-Kong and the Song-Koi, has detained us a long time. I was specially interested in proving their perfect ethnical independence, as far as their northern neighbors, the Chinese, are concerned, although they were their masters long enough to impose upon them their mode of writing, their system of mandarins and many other things, but whose supremacy has never succeeded in altering, in any way whatever, the ethnical characteristics of their subjects. The Annamites, who have been thoroughly studied, as a race, in French Cochin China and Tonquin, have undergone no external modifications that could be ascribed to these intermarriages. To say the most, there have been found among the Tonquin people some taller and mesaticephalous people, a fact which has been ascribed to the intervention of Hôs, immigrants from China, who were taller in size and longer of skull. In the Eastern Peninsula, as everywhere else, the Chinese who marries a native woman finds that the offspring of this union, Minh-Huong, reproduces the features of the mother. At

Saïgon, as at Batavia, Manila, etc., grandchildren retain next to no mark of their grandfathers.

In the pursuance of our investigations, and while getting gradually farther and farther away from the initial Mongolian type, we have examined in its minutest details the Indo-Chinese or Trans-Gangetic branch; then we have analyzed two other groups of races, of far less importance, and which, before my own researches, had never been thought of as constituting small ethnical groups of their own.

The first of these small branches, broken off, if we may say so, from Prichard's allophylous bush, comprehends the majority of the populations of the northeastern coasts from the Sea of Okhotsk to the peninsula of Alaska, Koriaks, Kamchadals, Chukluks, Chukchis on the shores of Asia, Aleuts, or Ununguns in America, on the islands and at the point of the peninsula, which constitute this ethnical group of 25,000 men at best, imperfectly bounded no doubt, especially eastward, but existing beyond all doubt. It is interesting to ascertain that the geographical area of this group, which until now has had no name of its own, exceeds the size of the Continent of Asia and very evidently encroaches upon the New World. We shall later on meet with other similar facts, which, we are convinced, will not fail to throw a certain light upon the fact that the majority of the tribes of the New Continent owe their origin to Asiatic ancestors.

However this may be, we place systematically after the Tibetans and the Indo-Chinese, who are subbrachycephalous, the Chukluks, whose average indication, 79.9, stands at the extreme limit of mesaticephally, and not far from them, the Tungus-Manchu (300,000 individuals), another breaking up of Prichard's "Allophylians," with their clearly mesaticephalous skull, which is at the same time excessively flattened. This is, I repeat, an entirely systematic process; we shall be justified in pursuing it, since it has enabled us to avail ourselves of the only characteristic features which are known with tolerable accuracy, the anatomical features. For they alone permit us, thanks to their clearly pronounced nature, to form a small, quite solid group, which may later on serve as a starting point for new efforts at classification. The whole of this remotest Siberia, the whole of this grand northern China, are territories overrun by small agglomerations of Nomads, which are usually only known by a few, rare photographs and a few tools seen here and there in collections. There are certainly among them some who, according to Pruner-Bey's expression, establish a connection with the boreal American. The Ghiliak of the Trans-Amour appears thus like a kind of intermediary between the Tungus and Inuit or Eskimo.

This last group, which contains 27,000 to 28,000 individuals, constitutes an ethnical whole of its own, relatively quite homogeneous, which once more presents to us the sight of a race having one end of its habitat in Asia, but having slowly reached, all along the boreal

ocean, the extreme northeastern part of the New World, Greenland, at the very time when it sent forth its most advanced tribes to reach the Falls of Niagara, though without going beyond them. I have here only briefly indicated the most essential features in the history of these Hyperboreans. It seemed to me more convenient to give you a detailed account of these various groups when I should present you the other natives of the far north of America. I do not, on that account, attach less importance to the ideas which I have always maintained as to the position which ought to be assigned to the Eskimos at one end of the line, of which the Mongolians occupy the other end. They are the true dolichocephalous members of Mongolism, as I shall show you in a few days. In the order of campaign which we have adopted they are separated from the Aleuts, with whom quite recently M. Virchow confounded them, by the Tungus-Manchu, whom we have just slightly reviewed, and by the Chinese, whom we shall yet have to investigate rapidly, so as to make an end of our studies as far as this whole great yellow host is concerned.

The Chinese, who are the most numerous of all yellow races (the least exaggerated numbers still give to China a population of more than 300,000,000), differ decidedly from all the other Asiatics whose essential features I have recalled before. Their hair, their complexion, their eyes, it is true, do not present any very decided peculiarity, but the bones of the skull and of the face offer forms and proportions which are not met with outside of what might be called the zone of Chinese influence.

Von Baër, who was the first to call attention to this special morphology of the Chinese head, expressed himself in a very picturesque manner when he tried to describe it. He had spoken of Buriat and Kalmuck skulls. "Imagine," he added, "you had the mold of a Kalmuck skull, made of some elastic material, such as gutta percha, and you were to compress with both hands the two sides of the top so as to make the brow rise and the top of the head and the occiput to stand out more boldly; compress then," he added, "the zygomatic arches so as to make them narrower and so as to cause the jugal bones, and especially the maxillaries, to appear in profile toward the front, and you will have the Chinese type."

The skull of the Chinese is, in fact, both longer and higher in proportion than those of all other yellow men. His cephalic index falls down to subdolichocephalism (the average indication of 142 skulls of the two sexes=77.24) and its height slightly exceeds its width. The face, harmonizing completely with the skull, is always of medium dilatation, with high and prominent cheek bones, and jaws which protrude in narrow and lengthened prognathism.

All true Chinese, whatever their origin may be, maintain more or less strictly the osteological type that I have here defined. No doubt the external features vary at times, vary very greatly, indeed; the

complexion, for instance, which at the north is white with a tinge of citrine, may at Canton darken to a deep brown; the almost horizontal eye may change into one more or less oblique; the nose may become flatter or be raised higher; the face may change to one more ample and more massive; the figure, the corpulency may undergo serious changes. But beneath all these external variations the osteological type always continues most tenaciously, and the anthropologist may ascertain that the collections of heads preserved in France, in England, in Holland, or elsewhere, give the same measurements with unfailing constancy.

The morphological changes are, therefore, all on the surface, and the absolute uniformity of the skeleton is complemented by a corresponding identity of costume, manner of walking, etc. This vast nation, the first in the world in point of numbers, is almost entirely subject to common usages and identical manners. The queue, which the conquering Tartars compelled them to wear in the seventeenth century, dangles now on the back of all Celestials, and the long nails, protected by metal sheaths, are at the south as at the north symbols of idleness and wealth. On the other hand, the custom of deforming women's feet, so characteristic in central China, has never been adopted by Chinese women in the south, and the wives of Manchus, the princesses of the now reigning Imperial family especially, have feet like everyone else.

We have given very special attention to these various ethnographic peculiarities and we have left the Chinese only after having summed up as exactly as it could be done all that can aid us in improving our knowledge of this people, of their intellectual manifestations as well as of their physical appearance.

I have taken especial pains to trace the history of their legendary migrations, starting from the northwest, and to show you how the first occupants of the lowlands near the great streams of the east were driven back, step by step, toward the mountain regions of the south and southwest, where we shall meet them again under the name of Lolos, of Miao-tsé, etc., in our search for the cradle of the Indonesian tribes.

I have as yet said nothing of Korea, which was so long looked upon as a simple annex of China; nor of Japan, which ethnologists quite recently considered only another Cochin China.

The Koreans and the Japanese belong without contradiction, at least up to a certain point, to the great mass of peoples of the yellow race. The Koreans, whom I have shown you in photographs, used so greatly to resemble Tibetans, that they were often mistaken the one for the other; but there are others who make the impression as if they were the offspring of intermarriages, and more than one modern traveler, unable to explain some national variations that might be called out of order, has brought in the most unexpected elements to account for

these strange mixtures, from the Aleutian (Chaillé-Long-Bey) to the Turk himself (Varat).

As to the Japanese, the immense anthropological collection (54 skeletons, 403 skulls, 27 pelves, etc.), sent to the Museum by M. Steenackers, shows the superabundant multiplicity of their various sources. It can hereafter no longer be doubted that the population of the Archipelago of the Rising Sun is connected by bonds of kinship with its neighbors on the Yellow Continent. But it is also becoming more and more certain, that some southern elements have played a very important part in their history as a nation. The Malays (to adopt a very general term), whose fleets ravaged the coasts of Tsiampa as late as the eighth century, had at times previous to that a powerful influence on the northern islands, and have left behind them numerous traces of their intervention. I shall take pleasure in seeing the ingenious and varied arguments brought to light by which M. Metchnikoff supports the very precise views which he has formed on that subject.

One last national element, which has remained very modest in its influence, because it was driven out with a kind of repugnance, by the Japanese, is the Aïno, the hairy race of Kuriles, of Sakhalin, and of Yeso. I have told you what little I knew of these singular islanders, whom for the moment I am utterly unable to classify. The Aïnos are, on an average, akin to the Chinese by their cephalic index, and I have provisionally placed them between the Chinese and the Eskimo, whilst most readily admitting that this classification is altogether provisional only.

Of the different branches of the yellow trunk, whose general physiognomy I have placed before you, those that could be gathered together in a tolerably homogeneous group without doing much mischief, have thus been passed in review. There remain to us to be studied a certain number of others, more or less irregular, and who, since Blumenbach, have been generally set apart under the names of the Malay branch and the American branch. This year's course of lectures will be devoted to the examination of documents of all kinds relating to these two branches.

We shall pass in review, successively, the material referring to the Korean and the Japanese races, considered in the light of intermediaries between those of the Asiatic Continent and those of the large islands which are dependent on them. Next we shall approach the facts which have reference to Malay land and its ethnological connections, Madagascar on one side, Polynesia and Micronesia on the other. This first series of studies will bring us to Easter. After vacation we shall begin the study of the races of the New World, which will occupy the whole remainder of the course.

COMPULSORY MIGRATIONS IN THE PACIFIC OCEAN.[1]

By OTTO SITTIG.

The fact that the first voyagers around the world found all the archipelagoes in the Pacific Ocean inhabited as far as Easter Island in the extreme east appeared to present an indecipherable enigma to anthropogeography, and although the remarkable skill of the Oceanic peoples in swimming, and the high degree to which they had developed the art of navigation were known, even these did not afford adequate connecting links for the origin of these islanders. Therefore, the first opportunity of considering the question with a prospect of success was afforded when instances of longer voyages, which exceeded the distances ordinarily traversed, became known and—this is the main point—also the fact that they occurred involuntarily. In connection with their accounts of such voyages, most travelers have expressed an opinion concerning the origin of the inhabitants of Polynesia. The view that they were indigenous to the soil met with no permanent approval, since from the very beginning there has been a conviction that there is a relationship not only between the Polynesians, but also between them and the inhabitants of the Malay Archipelago, and the idea of indigenous origin is on the whole mythical, so far as our knowledge of the people is concerned. The theory of their derivation from the islands southeast of Asia is therefore strenuously defended. But the opposite opinion, which assumes America to be the starting point of the population of Polynesia, is also mooted and finds its principal champion in Ellis. This view denies the possibility of a derivation of the Polynesians from the west, since the prevailing winds and currents move in that very direction and, moreover, there is no lack of ethnographical points of resemblance between the people mentioned and the original inhabitants of America. Of minor importance, in our consideration, are the individual opinions of Bary, Lesson, and, later, Quatrefages, who attribute the origin of these islanders to New Zealand.

The purpose of the present article is to make the most complete compilation possible of the cases recorded by history in which vessels have been driven out of their proper course in the Pacific Ocean, whose examination altogether may afford us an insight into the natural hypotheses of migrations across the ocean.

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[1] Translated from Petermann's Mitteilungen, 36 Band, 1890, VII, VIII.

The chart upon which have been mapped out the course of compulsory voyages shows very distinctly four separate districts in which craft are driven out of their way, according to which this discussion is naturally divided. These four districts, which will be examined successively, are the following:

District I.[1]—The islands between the Philippines and Gilbert Archipelago from 0° to about 15° north.

District II.—The islands west of Samoa and Tonga from 0° to 22° south (western boundary of New Guinea).

District III.—The islands east of Samoa in the same latitudes (eastern boundary, Crescent Island).

District IV.—The northern basin of the Pacific Ocean.

The results of our argument will form anthropogeographic conclusions, to which we shall be led by the material gathered.

DISTRICT I.

The first of the districts marked out above lies in the monsoon region of southeastern Asia; here the vicinity of the continental masses of land exerts an influence which greatly modifies the action of the winds. Hence, just in this region, instances of compulsory migrations accumulate, and we find a fitting motive to the first field for examination in the accidental voyages which start from the Malay Archipelago or find their goal there. Reports of such in former times exist in the descriptions which Spanish missionaries and travelers give of the Philippine Islands and neighboring groups. In the year 1638, a ship called *Conception* was driven from Manila to Tinian, one of the Ladrones.[2] From the letters of the missionaries, De Brosses states[3] that, in the year 1696, twenty-nine Pelew islanders, or natives of islands previously unknown, were driven in two boats to Guivam, on the island of Samal. The wind tossed them about for seventy days, and five of their number died from the exertions and privations of this voyage of 800 kilometers. At the same time two women were found on the same island who had been

[1] We have intentionally avoided the usual names Micronesia, Polynesia, etc., because the natural conditions compel us to assume a uniform population of the Oceanic islands, and such a distinction in the nomenclature might easily lead to an opposite comprehension.

[2] De Brosses-Adelung: Complete History of Ocean Voyages, page 553, and De Brosses: Voyage aux terres australes, Vol. II, page 443.

[3] The same, page 350. Cook: Third Voyage, French ed. I, page 254. Note Omai: Reports, etc., page 109. Ellis gives in Polynesian Researches, I, page 125, forty persons; so also does Malte-Brun, according to Palmer: Kidnapping, etc., page 30. One of the castaways died soon after the arrival; there is also a difference of ten persons; but this seems later to have been merely an error in print. According to Semper: Pelew Islands, page 356, it appears from the statements of Father Murillo Velarde (Histoire, etc., page 375, and following Manila, 1749) that these islanders can not have been natives of Pelew, which the name of the island, Panlog, controverts, but must have come from Yap, or still farther eastward. (The lettres édif. also oppose it.)

brought there by a similar accident. It might be supposed that inhabitants of the Philippine Islands would also have been carried to the Pelew Islands, but this conjecture is not confirmed. There is not a single instance of such a compulsory voyage, but there are transactions which can explain this phenomenon. These are the futile efforts made by the Spaniards to reach the Pelew Islands from the Philippines, which are related by De Brosses and Burney[1] from the travels of Franciscus Padilla. The first effort of the Spaniards to discover the "New Philippines" occurred in 1707, after a shipwreck suffered by some of the inhabitants of these islands, whereby they became known.[2] But this was frustrated, as were also four other attempts, which were undertaken in the years 1708, 1710, 1711, and 1729. The first time any one succeeded in sailing from the Philippines to the Pelew Islands[3] was in 1731. These noteworthy circumstances teach us the close connection existing between accidental voyages, and thus also the migrations of the Oceanic peoples, and the mechanical movements of the wind and the sea.

There are, however, instances of vessels being swept from more southern regions to the Pelew Islands. Captain Wilson, after his shipwreck in the year 1738, found at Pellilu a Malay who, with six companions, had been carried thither from Ternate in the Celebes.[4] Dumont D'Urville also mentions this case.[5] A thoroughly analogous event happened, according to Johnson's statement, in the year 1859 and in the following one, when two boats from Salibago were driven upon the northwestern side of the Pelew Islands. The crews landed at the village of Aibukit, and Kubary afterwards found one of the castaways still there.[6] Micklucho-Maclay, during his brief stay in Yap and Pelew, also frequently met persons from other islands who had been cast away on them: for instance, he found on the main island, Baobel-taop, in the village of Malogiok, a man from Bul, on the northern coast of Celebes,[7] who made his voyage in eighteen days.

In the first group is one of the most remarkable and at the same time also the best known voyage which is related of Kadu. The Russian captain, O. v. Kotzebue,[8] met him on the island of Aur. Chamisso, Kotzebue's traveling companion, was induced by this singular case to pay special attention to compulsory migrations. Kadu was a native of the Ulie Islands, and with two of his countrymen and an inhabitant of

[1] History of the Discoveries.

[2] De Brosses-Adelung, page 429 and following.

[3] E. Butron de la Serna, in Bol. Soc. Geogr., Madrid, 1885, page 23, and Lettres des Missions, X and XI.

[4] Semper: Pelew Islands, Supplement 11. Lesson: Les. Polyn. et leur migrations, I, page 369.

[5] Voyage au pole sud et dans l'océanie, V, page 208.

[6] F. Ratzel: Völkerkunde, II, page 340 and following.

[7] Ibid.

[8] Reise um die Welt, I, page 103.

the island of Yap, while on a voyage from Ulie to Fais, was overtaken by a storm, and after drifting a long time was cast ashore upon the Aur group of the Radack chain.[1] Thus, the wind had driven the luckless voyagers a distance of 2,700 kilometers.[2] Kadu was taken on board of the *Rurik*, where Chamisso especially interested himself in him, and from the narratives of our man of Ulie noted a series of similar cases which he himself deems reliable. An event precisely analogous to this is the casting ashore of seafarers from Yap upon this same group of Aur where Kadu was found. The latter distance even exceeds the former by 300 kilometers. In Chamisso's time there were also five natives of Lamotrek living on the southeastern side of the Arno group, who had been borne there by the wind and currents. In 1857 people from Ulie were driven to the Marshall Islands in the same way.

It is not without some astonishment that we find ourselves in the presence of this immense number of compulsory voyagers, since their course is exactly opposite to what we should expect from the mechanical movements of the waves and the wind in this group. In fact, there is also no lack of accidental sea voyages in the contrary direction which appear to us much more significant. Thus, Chamisso met at Guahan a native of Lamotrek who knew the names of Radack and Ralick, and this circumstance, though not with absolute certainty, indicates a castaway from the chain of islands farther westward.[3]

There is a noteworthy event which occurred about the year 1807, when a boat was driven from Tuch to Guahan, that is, about 800 kilometers, in a northwestern direction.[4] De Brosses gives two similar instances from the letters of A. Cantova.[5] On the 11th of June, 1721, and two days later people from Faraulep who wished to go to Ulie, but were driven about twenty days by wind and tempest, were stranded here.[6] According to Cook,[7] who, in his third voyage, also mentions these events, there were twenty-four people in the first boat, while the latter contained only six. In the same way, during the previous year, two canoes were swept from a distant island to one of the Marianne group, but it is not stated whence they came. It is, however, certain that in the period between 1760 and 1770, a boat from Yap, lying 800 kilometers toward the southwest, was cast ashore on the same island of

[1] Reise um die Welt, I, page 103.

[2] The estimate of the length of such voyages is especially unreliable, where months are taken as the basis of the measurement of time. Kadu gave eight months; M. Waitz (Anthropologie, I, p. 225, and V, p. 21), only five months are named.

[3] Chamisso: Bemerkungen zur Reise um die Welt, page 127. Quatrefages, page 105; Palmer, page 30. Bastian: Inselgruppen, page 104.

[4] Chamisso: Bemerkungen zur Reise um die Welt, page 140.

[5] De Brosses-Adelung, page 553.

[6] Ibid., page 464.

[7] Cook: Third Voyage, I, page 251, note (Lettres édif. XV, pp. 196–215). In Burney, where these two cases are mentioned, A. Cantova's letter to d'Auberton is given.

the Marianne cluster.[1] A chief from Faraulep, just mentioned, was once driven by accident upon Mogmog, near Yap. He set sail for Guahan, but missed his way; and the same voyage was once made by a little boat which carried only three men, but sailed faster than the two larger vessels with which it came.[2] A very remarkable case was related by Rua, a native of Nukuor. He left his home on the 6th of December, 1876, and with a coverlet for a sail tacked about for seventeen days to reach Ponapl, but missed it and was stranded on the Minto Reef, 450 meters due north of his starting point, where he was obliged to support life until September, 1878, when the schooner *Lotus* found him and brought him to Tuch.[3]

The other instances of compulsory voyages in our first district belong to the eastern islands, and bring these groups into connection with each other and also with the western ones. Radack and Ralick maintain a constant intercourse and therefore accidental voyages frequently occur here, though of less length than in the examples previously cited. While Chamisso remained in Ailuk a young chief from Mesid (probably Mejit, only 100 kilometers eastward) was driven ashore there in a little fishing boat by a tempest:[4] and many years before five persons from Repith-Urur, an island of the Gilbert Archipelago,[5] were cast upon the island of Relich in the Ralick chain. Besides, there were on the island of Airik of the Kaben group, a man and a woman, and on Arno, formerly mentioned, two men and a woman, also from Repith-Urur, who had been borne thither by the winds and current. During Kadu's residence on Aur two boats, each containing a man and a woman, arrived there from the same island of the Gilbert Archipelago.[6] Lastly, a case very interesting in itself and analogous to that of castaways, though less important, is the appearance of driftwood and the floating of the wreckage of ships, when the question is the possibility of the dispersion of peoples over the ocean in connection with the mechanical movements of the atmosphere and the sea.[7] On Tabual Island, of the Aur group, Chamisso found a woman from Bogha, who, while trying to carry leaves of the cocoanut palm from one island to another, was caught by the tide and swept away; her cocoanut fronds served as a raft, and five days after she was washed ashore on Utirik.[8]

[1] Chamisso: Bemerkungen, pages 117 and 140.

[2] It is known that people from the Caroline Islands often sail to Guahan; therefore instances of vessels driven out of their course frequently occur in this region.

[3] Ethnograph. anthropol. Abteilung des Museum Godeffroy in Hamburg, page 342.

[4] Chamisso: Tagebuch, page 195.

[5] Ibid.: Bemerkungen, page 148.

[6] Ibid., page 184.

[7] We might here express the conjecture that the dissemination of the cocoa palm, and especially of certain land animals, would be found associated with the dispersion of human beings. For instance, there are uninhabited islands, and these are destitute of these palm trees, as the Ducie Islands (Paumotu); Timoe, on the contrary, lying about 10 degrees westerly is inhabited, but has no cocoa palms. (Zeitschr. d. Gesellsch. f. Erdk. Berlin, 1870, p. 346.)

[8] Chamisso: Tagebuch, page 184. Kubary: Ethnogr. Beitrage, pages 47 and 120.

But still larger numbers of the inhabitants of the Marshall and Gilbert islands were carried out of their course and cast away farther westward in the center of the Carolines. This fact may already be conjectured from Kadu's tales. According to his statements, "Fanopé" must be groups of low islands, whose existence became known by the frequency of voyagers from thence being cast upon Puluhot; besides, Kadu had learned on Puluhot a song in which a distant group of islands, Malilegotot, is mentioned.[1] Fanopé is scarcely identical with Ponape, which shows a series of names that have a similar sound, because the latter island is mountainous. Nor do we suppose that Funafuti or Fuana-tapu of the Ellice Islands is meant; but at any rate, long compulsory voyages from west to east must be the foundation of such traditions. Besides, we do not lack well-authenticated cases of the same kind. In the year 1856, a boat was swept from Ralick upon Kusaie of the Caroline group, and a few days later another was driven ashore upon the island of Mokil or Wellington, lying still farther west;[2] that is, a compulsory voyage of nearly 1,100 kilometers was made with the wind and the current. It is also worthy of note that the inmates, in spite of the forces working against them, succeeded in returning home. Men from the Marshall Islands were also cast ashore upon the Gilbert Islands lying toward the southeast: for instance, in the year 1861; and, on the other hand, inhabitants of the former were swept upon Radack and Ralick.[3] Hernsheim reports[4] the indubitable fact that inhabitants of the Marshall Islands were carried farther to the Carolines, to Pleasant Island, and still westward for distances of 2,700 kilometers. For instance, he himself took from Hongkong to their home, the Kingsmill Islands, four native Mainas who, while on a short cruise from one island to another, were surprised by a violent storm, and in ten days carried to 2 degrees south and 161 degrees east—that is, a distance of 1,300 kilometers. There they were taken on board a French ship. The authenticity of a similar event is vouched for by the French missionary Maigret. During his residence in Ponape, in the year 1837, he saw a man who had landed there by accident from Marakai, in the Tarawa group; on the other hand, it is asserted that this very Marakai obtained its population from Ponape: the islands are 1,500 kilometers apart, and therefore, in this instance, it is an especially favorable circumstance that the migration is compulsory. At the same time two boats came to Tarawa from an island of the same Gilbert Archipelago,[5] lying southeast of it, called by Hale Amoi.[6]

[1] Chamisso: Bemerkungen, page 148.
[2] Nautical Magazine, 1858, page 403.
[3] Bastian: Inselgruppen, page 104.
[4] Mitteilungen der Geogr. Gesellsch. Hamburg 1885-86, page 303.
[5] The Gilbert islanders build their boats of driftwood (Zeitschr. d. Ges. f. Erdk. Berlin, N. F. 15, p. 370; and North. Pac. Sailing Directory, p. 939).
[6] United States Exploring Expedition, V, pages 85, 182, and 190.

DISTRICT II.

In leaving the first and most diversified of our districts, we can name only a single instance of a compulsory voyage, which forms a bridge across the region of calms to the group of islands mentioned in the introduction as belonging to the second district. It is a fact that an inhabitant of the Kingsmill Islands was once driven to Rotumah.[1] An inhabitant of this latter island was carried to Samoa, and this voyage must have lasted not less than three months. Another Rotumah man reached Viti. Almost the opposite voyage, in a little more easterly direction, was made by Kow Muela, a Tongan, who had gone with a band of young men to the Viti Islands on an expedition. After he had harassed this archipelago for two years he sailed for Tonga, but at Vavau encountered unfavorable winds and was compelled to shape his course for Samoa, but reached Fotuna,[2] lying to the northwest. All the other accidental voyages in our present district show a common noteworthy characteristic—they all, with slight modifications, take the same main direction from west to east.

Cook and the Forster brothers noticed the kinship which the inhabitants of certain islands of the New Hebrides showed to the Tongans and Samoans, but there was no attested fact which could have explained the necessity of such a relation. The second voyage[3] which Captain Bligh's boat, after his landing in Toto, made in a westerly direction—it finally landed at Timor—sufficiently proves that compulsory migrations from central Polynesia do take place for considerable distances with the trade winds. Of course, in such occurrences the Viti Archipelago could not remain exempt, and, in fact, through the reception of Tongan blood, a mixed race has been formed, which occupies the windward side of these islands, and about 200 pure Tongans also live on this group.[4] Here, it is true, the normal relations of traffic also exist, and the Tongan boat building in Viti, etc., must not be overlooked. It is the eastern winds which drive them there. Lakemba became their principal settlement, and when the missionaries arrived there were three Tongan colonies on this island.[5] But Tongans and Samoans were also driven still farther westward. Thus Erskine found in Nengone three descendants of Tongans who had been swept ashore there many years before in several canoes by a strong wind.[6] Turner, who remained a

[1] Waitz: Anthropologie der Naturvölker, V, page 20. Polack: Narr. II, page 427. D'Urville, V, page 362. Dillon, I, page 294.

[2] Mariner: Tonga, Neue Bibliothek der Reisen, Bd. XX, page 276.

[3] Expedition of the *Novara*, II, page 229, two volumes, by B. v. Müllerstorf-Urbair. Bligh: Voyage in the Pacific; Account of the Mutiny.

[4] Cruise of the *Curaçao*, page 140. At Home in Fiji, by G. Cumming, II, page 289.

[5] Ten Months in the Fiji Islands, by Smythe, page 124.

[6] The Islands of the Western Pacific, page 373, Meinicke: Die Inseln des Stillen Ozean, I, page 375, note 14.

long time on the western group of islands in the Pacific, found at Vate the blind chief Bula, his interpreter, and several young people who were descendants of Tongans, and had also come there by accident.[1] Bula called himself Sualo. He left Samoa in a double canoe about the time of the Atua war (1825) in company with fifty other persons, principally Tongans. They lived a number of years in the new home to which the wind had borne them, but when they set out to seek the old one they missed their native islands, and remained permanently on Vate. Turner also found on the island of Lifu Polynesians who, like Bula and his companions, had been carried to this western island. It is also stated that people have been driven upon Tanna from Samoa and Tonga. The islands of Erromanga and Immer have undoubtedly been peopled from the east by a race whose dialect is akin to that of Tongan. Their inhabitants had thus made the same journey as their countrymen on Tanna.[2] Codrington, who is well acquainted with the Melanesian languages, mentions in the western range of islands in our second district a large number of localities which have received Polynesian elements of population, and he, too, attributes these immigrations to accidental causes. Besides Uvea of the Loyalty Islands, he cites Fotuna, which is identical with Erromanga or Eranan, already mentioned, and Vate. This influence also extends to several islands of the Shepherd group, and shows itself especially in the one seen by Cook and named from its position Mai, or Three Hills. But he goes still farther, and not only includes the district north of the Banks Islands (Tikopia) and the Swallow group (Matema), situated near Santa Cruz, but, with Bennell and Bellona, embraces the southern, and with Ongtong Java, near Isabella, the central Solomon group. Codrington himself met on the island of Ureparapara, one of the Banks group, a man and woman with their son, who had been cast ashore there from a Polynesian island; and even at Saddle Island[3] he found children who were descendants of Polynesians who had been stranded there. Lastly, just before his stay on the Banks Islands people had arrived two successive years from Tonga and remained a considerable time.[4]

[1]Nineteen Years in Western Polynesia, page 398. Bastian: Inselgruppen, page 87. Murray, Missions in Western Polynesia, also relates this event, page 233. According to him, there were Samoans in the party.

[2]Bastian: Inselgruppen, page 87; Garnier reports immigrations from Viti into Lifu. Ibid., page 180.

[3]Saddle Island in Torres Strait can not be meant, as an island lying nearer would probably have been reached.

[4]Codrington: Melanesian Languages, page 7 et seq. Hale states that Quiros had taken a man prisoner on Taumako, who told him that arrows had been brought to this island from a distant country called Pouro. He supposes Pouro to be in the Indian Ocean and thinks that the arrows must have come from India; but Guppy corrects this, and says that the place meant is Bouro, which lies only 500 kilometers west of Taumako, while Pouro is more than 3,600 kilometers. (United States Exploring Expedition, V, p. 195. See also Burney, History of the Discoveries, II, page 308.)

DISTRICT III.

The farther we go from the masses of land forming the continents lying eastward and approach the third district, where vessels are driven from their course, the shorter becomes the series of instances recorded by history of compulsory voyages which are to give us a clearer comprehension of the intermingling of the Polynesians; yet even here they are not wholly lacking, and present almost the greatest wealth in regard to the line of direction.

The province now to be considered is united with the former one by three long accidental voyages. The boat of the Englishman Williams was once driven from Rarotonga to Tongatabu, that is, a distance of more than 1,500 kilometers, and on his last voyage he himself conveyed to their home several natives of Aitutaki who had been carried by the wind to Probys Island (Niue Island), which lies 1,500 kilometers westward of Cooks or Herveys Island.[1] The third connecting route presents itself in 10 degrees south, and extends far beyond the eastern limit of the second district. In the year 1861, inhabitants of Manihiki or Humphrey (10° S., 161° 1′ W.) were swept away by a storm and reached Nukulailai: one of them, Elkana, on this occasion gave there and in Funafuti (the Ellice group) the first Christian instruction.[2] An inhabitant of the austral island Rurutu was once transported to this same island, Manihiki; his wanderings lasted six weeks.[3] And in the year 1820 a canoe, also from Rurutu, arrived at Uliatea, in Maurua, having accomplished this voyage of 900 kilometers in from two to three weeks.[4] From this region of Maurua we have to note two cases which extend to the Hervey group. In 1824, a boat which belonged to Mr. Williams left Raiatea (Uliatea) with a westerly wind to sail to Tahiti, but the wind changed, and the boat, several months later, was found 1,400 kilometers toward the southwest. Another time Williams's own boat was driven from Tahiti to Atui. Shipwrecked voyagers were found by Cook on the same island. During his second voyage he took with him to England Omai, a native of Raiatea, who accompanied him on his third voyage. When they reached Atui, Omai found three of his countrymen who had been driven ashore there when they were sailing homeward from Tahiti. Besides Omai's acquaintances there were seventeen others in this party.[5] Captain Bligh found on Mäatea a boy and a woman, the sole survivors of an unfortunate band who had been carried there some time before his arrival from Tubuai.[6] Ellis reports

[1] John Williams: A Narrative, etc., page 132.

[2] Zeitschr. d. Ges. f. Erdk., Berlin, 1868, page 131.

[3] Williams, page 469.

[4] Ellis: Polynesian Researches, I, page 125. Hartwich: Die Inseln des Grossen Ozean, page 334.

[5] Cook: Third Voyage, I, page 252. Omai: Reports, I, page 109 and many others.

[6] Bligh: Voyage in the Pacific, I, page 125.

that frequently people from eastern islands of which nothing had been previously known on the Society Islands were cast on the shores of Tahiti.[1]

In the small number of instances in this eastern district of the region where boats are driven out of their course, compulsory voyages against the wind are not largely represented; but they are not entirely wanting. Thus it is positively proved that the austral island Tubuai,[2] previously mentioned, was peopled at a recent date, 1840, by natives of an island lying westward, probably Rimitara, and the immigrants were brought there by unfavorable winds.[3] Timoe or Crescent Island also received its population accidentally and from the west, namely, from Mangarera.[4] Lastly, the case of voyagers being driven from Raiatea to Tubuai is also assured to us.[5]

It would be of special value to our position if we could record an instance of an accidental voyage to Easter Island,[6] but though this is not possible, there are two actually certified voyages against wind and current from the Paumotu group which are analogous to the case we must assume in order to bring the Easter Islanders into connection with the other Polynesians. Captain Beechey[7] found on the island of Byam (Martin) forty Tahitians—men, women, and children—who had been swept in a double canoe against the prevailing wind from Chain Island to Barrow Island (Wana Wana), a mere reef, that is, a distance of about 1,000 kilometers. Beechey took one of these unfortunates, Tuwarri, on board, and when they reached Bow Island this Tahitian found his brother and various friends, who had been stranded there by the same disaster. The latter had first made a voyage with the wind, so that the total length of their passage was about the same distance—1,000 kilometers.[8]

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[1] Ellis: I, page 125.

[2] United States Exploring Expedition, V, page 130.

[3] Ibid., page 140.

[4] Ibid., page 130.

[5] Ibid.

[6] There is probably no doubt that Easter Island has also been peopled from the west. Beechey gives excellent reasons for it (I. 79). Micklucho-Maclay informs Bastian in a letter that Easter Island was known to the inhabitants of the nearest island as Rapa nui (Zeitschr. d. Ges. f. Erdk. Berlin 1879, 7). According to tradition, the population of this island came from Oparo, lying 1,900 miles westward. Images and stone slabs, like those in Easter Island, have been found there (Palmer, p. 29). Geiseler also supports this; but mentions a tradition, according to which the Easter islanders are said to have come from the Galapagos Islands; but this tradition is opposed to the opinions of other natives; besides, the Galapagos Islands were uninhabited. (Easter Island, an abode of prehistoric civilization in the South Seas, p. 43.)

[7] Beechey: Voyage in the Pacific Ocean, I, page 261. Palmer, page 30, and many others.

[8] It is also an important circumstance that Wilkes found driftwood at Enderbury (3° 8′ S., 171° 8′ W.) which must have come from the west. (Behm, in Petermann, 1859, p. 181); and Hale (p. 157) speaks of the wreckage of ships drifting upon

DISTRICT IV.

After connecting the individual groups of islands in the Pacific Ocean from Pelew to Paumotu, there is still the basin of the North Pacific. Instances of accidental voyages, whose point of departure lay within one of the districts already discussed, do not occur, and the point in question concerns only vessels from the continents, especially Asia, which have been swept out of their course.

The Bonin Islands (properly Bunin-Siam, that is, uninhabited islands) were discovered in the year 1675, when a Japanese junk was cast ashore there;[1] and in 1690 Japanese, who often made voyages to the Ladrones, were carried away to Manila.[2] In the year 1869, a Chinese junk, which had been swept from the Liukiu Islands, was stranded upon Baker Island. In 1836, the figurehead of a ship from China was found in Metalanim at Ponape.[3] It is singular that no connection from the groups of islands already established can be made with the Sandwich Islands. Vague traditions and ethnographical characteristics among the Hawaiians, it is true, point to Polynesia, but there is no event which would permit us to deduce positively that the natural conditions for bringing the Hawaiians into a necessary connection with the other islanders have existed.[4] Yet there are abundant reasons of a

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Fakuafo (9° 20' S., 171° 4' W.) of the Union group; also of the floating ashore of clubs which must have come from Viti or Samoa. The instance of a craft being carried out of her course to Raratonga is only to be inferred from the traditions existing there: people from the Society Islands are said to have arrived at various times by accident, but the Raratongans also trace their origin to Raiatea, and this coincides with the beliefs of the inhabitants of this latter island. (Ellis I, p. 126.) Beechey (I, p. 60) mentions various errors of reckoning, which we will pass over here. Behrens, a traveling companion of Roggewein, was driven, during his short voyage from the island of Juan Fernandez to Easter Island, 318 (corrected to 204) English miles farther west than he expected to be. With Blossom the difference in the same region amounted to 270 miles; and when La Peyrouse went from Conception to Hawaii, during which passage he touched at Easter Island, he noticed that he had made an error in his reckoning of 300 miles.

[1]Geogr. Handbuch, by R. Andree (for school atlas), page 370.

[2]From similar events in earlier times the fact may be inferred that in the eastern portions of the Malay Archipelago, for instance Ceram, legends of white immigrants had existed before the arrival of the first Europeans. (See Bastian Inselgruppen, p. 242.) On the other hand, Rein (Japan, p. 449 and following) maintains that natural conditions existed for tracing the population of Japan from the Malay Archipelago; other reasons, however, are decidedly against this conjecture.

[3]Waitz I, page 225; V, page 20; F. Ratzel: Völkerkunde II, page 340 and following.

[4]A ship was once wrecked on Fakaafo (Union group). Hale supposes that it came from Hawaii, because the word "debolo" (in Fakaafo, it is true, with a different meaning (is found in both places (United States Exploring Expedition, V, p. 157.) Traditions of voyages to Nukahiva are not lacking in Hawaii; voyages to Tahiti are even said to have been undertaken (Bastian-Inselgruppen, p. 286.) The general opinion is that the boats of the Hawaiians were formerly larger; voyages were said to last two or three months. (Ellis: Tour through Hawaii, p. 441.) A direct relation is even said to have existed between the New Zealanders and the Sandwich

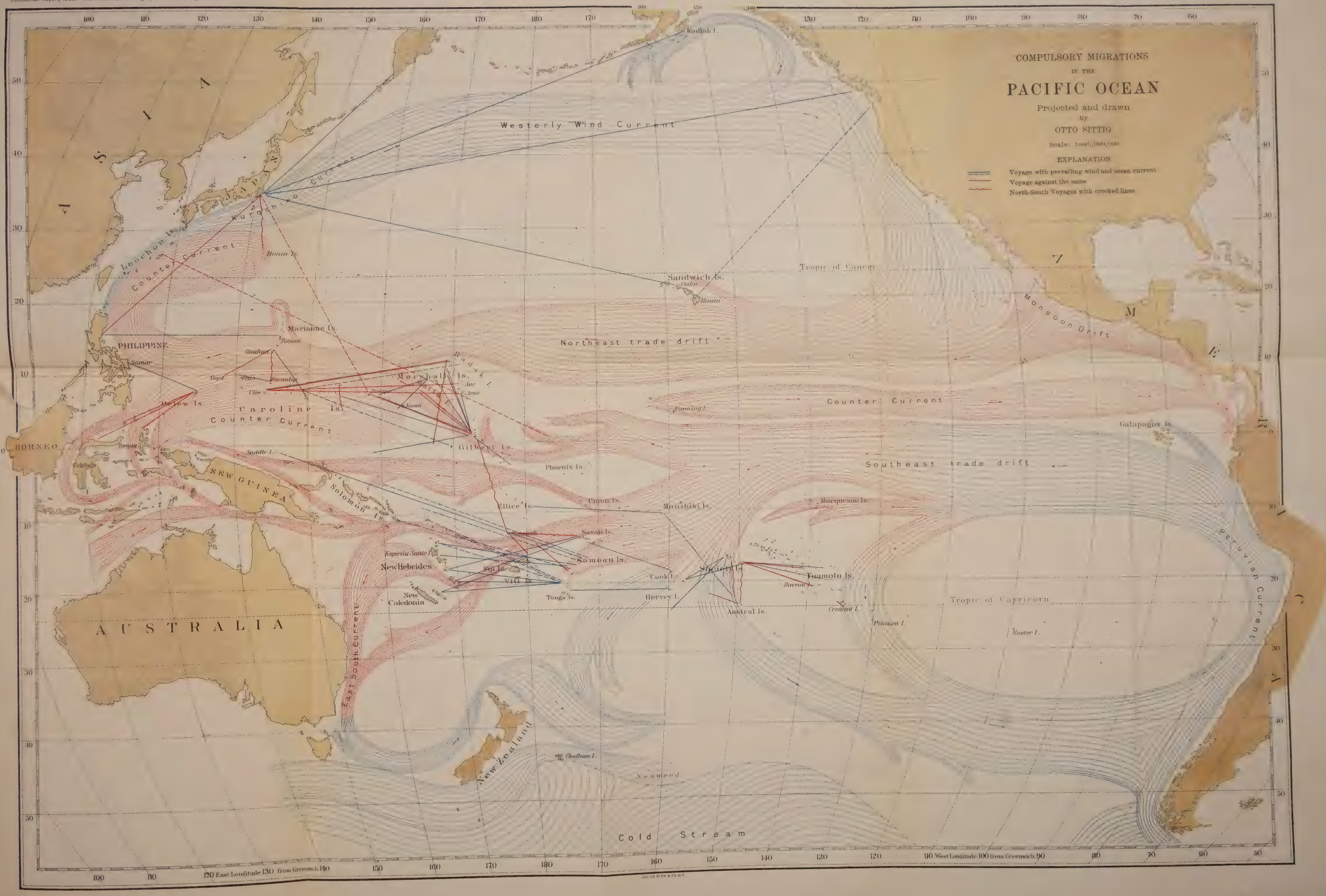
different character, which compel us to believe in a kinship between the Hawaiians and the other Polynesians. In the ancient population of Malden and the vanished one of Fanning, we find the unmistakable bridge between the Society and the Sandwich islands.[1] There has always been a conviction that an influence from China, and especially from Japan, has asserted itself here. Cases of craft from eastern Asia being driven to Hawaii remove any doubt of this fact. Besides, these cases are especially calculated to prove to us how closely the population of Polynesia is united to that of Asia.

According to the statements of the Hawaiians themselves, such occurrences are not infrequent. Jarves relates that in December, 1832, a Japanese junk was driven ashore at Oahu, near the harbor of Waialea. Nine of its occupants were still alive. after having been tossed to and fro eleven months upon the sea.[2] The remark made by Hawaiians upon the arrival of these people is worthy of consideration. They said: "It is plain now we come from Asia," when they saw that the strangers showed a strong resemblance to themselves. In the time of Opili also, white men landed on the southwestern coast of Hawaii, and a reliable statement informs us that a short time after the departure of these strangers another band of white men were also stranded on the western side of Hawaii. The boat had neither mast nor sail and was painted. The people were dressed in yellow and white, and one wore a hat adorned with plumes. They long exerted an influence in Hawaii. Later, a boat is said to have arrived at the same place, and about the year 1620 a second one came to the southern side of the bay just mentioned, in Palekai. The ship was wrecked and only the captain and one white woman reached the land. Two vessels are also said to have once been cast upon the northeastern shore. but no one gained the beach. Wilkes states that a whaler received on board five Japanese and took them to the Sandwich Islands. There is a mythical story that, under the government of King Kamaloohua, in Maui, a Hawaiian vessel brought in four strangers, whose complexion was only moderately dark, and who were probably the crew of a wrecked Japanese boat. With the frequency of such cases, it can not surprise us that instances of compulsory voyages have been recorded which extend over the entire

Islanders; both cultivated—the former according to tradition—the sweet potato, which did not exist in the Society Islands. (Shortland: Traditions and Superstitions of the New Zealanders, p. 34.) Williams found in New Zealand a dog which lived in a wild state in Maurua (Samoa). He therefore seeks Sawaii there, and not in Hawaii, (Hood: Cruise of H. M. S. *Fawn*, p. 148.) Max Buchner lays stress upon a direct connection between the Hawaiians and New Zealanders. (Mitheil. d. Geogr. Ges. Hamburg, 1876–77.)

[1] Zeitschr. d. Ges. f. Erdk., Berlin, 1868, page 116.

[2] History of the Hawaiians, page 29; North. Pacific Sailing Directory, page 1209; United States Exploring Expedition, V, page 260, and many others. (See Waitz, V, p. 20.) [The reader should consult a pamphlet entitled The Long Voyages of the Hawaiians, by N. B. Emerson, Honolulu.—Ed.]


COMPULSORY MIGRATIONS
IN THE
PACIFIC OCEAN
Projected and drawn
by
OTTO SITTIG
Scale: 1=40,000,000
EXPLANATION
Voyage with prevailing wind and ocean current
Voyage against the same
North-South Voyages with crooked lines.
ASIA
JAPAN
PHILIPPINE
BORNEO
Celebes
NEW GUINEA
AUSTRALIA
New Zealand
AMERICA
Westerly Wind Current
Kuroshio Current
Loochoo Is.
Counter Current
Bonin Is.
Marianne Is.
Guahan
Caroline Is.
Counter Current
Marshall Is.
Gilbert Is.
Phoenix Is.
Ellice Is.
Union Is.
Manihiki Is.
Samoan Is.
Savaii Is.
Solomon Is.
New Hebrides
Espiritu Santo
New Caledonia
Viti Is.
Tonga Is.
Cook I.
Hervey I.
Society Is.
Austral Is.
Tuamotu Is.
Marquesas Is.
Pitcairn I.
Easter I.
Crescent I.
Chatham I.
Sandwich Is.
Oahu
Hawai
Kadiak I.
Fanning I.
Galapagos Is.
Northeast trade drift
Southeast trade drift
Counter Current
Monsoon Drift
Peruvian Current
East South Current
Tropic of Cancer
Tropic of Capricorn
Seaweed
Cold Stream
East Longitude from Greenwich
West Longitude from Greenwich
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basin of the Northern Pacific to the American Continent. The voyages to Hawaii may be regarded as transition stages to those to America. The analogy applies to two compulsory voyages, also of Japanese vessels, the first, which sailed for Osaka, was cast away on Cape Lopatka in July, 1729; the other was carried to the southern end of the island of Kadiak.

Kotzebue[1] states that Japanese have been carried to America, and about the time when the Japanese junk reached Oahu such a boat also landed near Cape Flattery, north of the mouth of the Columbia. Sometimes Chinese ships were even driven to the northwestern coast of North America.[2] In the examination of the Sandwich Islands, the fact is specially worthy of note that articles are transported here which show their origin in North America with the same cogency as the voyages previously mentioned indicate Asia. Vancouver found in Kauai a canoe 61½ feet long, which was hollowed from a single log.[3]

The prospects in the investigation in the case of New Zealand are meager. Probably no one doubts that this pair of islands obtained its population from an island centrally situated among the groups formerly discussed, and a glance at the mechanical relations of the Pacific suffices to make this easy of comprehension; but there is no positive proof of it. The report that a ship on the way from Savaii to Tonga was overtaken by a storm, driven toward Viti, and finally reached the coast of New Zealand is shrouded in obscurity;[4] and it seems almost superfluous to cite the instance of a vessel driven out of her course, which occurred on the northeastern coast of New Zealand. In June, 1844, a boat from Opotiki was carried to Tauranga, which is only about 120 kilometers westward. The single point worthy of note here is the fact that the incident occurred in consequence of a northeast storm.

The Chatham Islanders trace their origin to New Zealand, and have the tradition that about the year 1750 their ancestors were driven on shore by a westerly storm; but these must not be confounded with the New Zealanders who came there later for the purpose of trade.[5] We deem this fact of importance, as it lays stress upon the point that the primary act was the driving out of the course, and the secondary one

[1] A New Voyage, etc., Lond., 1830, II, pages 36, 48, 53.

[2] United States Exploring Expedition, by Wilkes (two volumes), II, page 295.

[3] North Pacific Sailing Directory, page 1209. In Hawaii (eastern side) two anchors were found; Kotzebue supposes that they came from one of the ships which were driven out of their course (see Jarves, p. 102); and the iron which Cook found in the same place is said to have belonged to Spanish voyagers from Manila. (Bastian: Inselgruppen, p. 242, note 2. Cook: Third Voyage, II, p. 402.) Cook thinks it entirely a matter of course that this iron must have come from the east. The frequency with which driftwood washes ashore along the whole northern rim of the Pacific is generally known.

[4] United States Exploring Expedition, V, page 147, and in reference to the Chatham Islands, ibid., page 148, note.

[5] Traditions and Superstitions of the New Zealanders, page 34.

the formation of commercial relations.[1] Yet other factors which compelled the Oceanic peoples to leave their native islands must not be overlooked. It is the nature of these islanders to trust themselves confidently to the sea, hoping soon to find an island where they can settle.

It is not surprising that we can record no vessel driven out of her course in the Southern Hemisphere, which extended to South America. Probably no one would assert that such an event happened, though it is not impossible. Dillon mentions, as a noteworthy example, that in June, 1824, an American ship ran into the harbor of Valparaiso, which had sailed from Mulgrave Achipelago, past Samoa, with the wind blowing constantly from the west and northwest. In the higher southern latitudes "the brave west winds" are proverbial with mariners. Since, under force of natural conditions, an immigration into South America from the west is not absolutely impossible, there is in some degree an analogy in the northern and southern basins of the Pacific with regard to the possibility of the dispersion of human beings.

But this analogy can exist only so long as the relations of the wind and currents in both basins are the same. In the vicinity of the equator—in point of fact slightly north of it—these relations are symmetrical, and complications of these relations first become operative when the groups of islands on the continents place obstacles in their way. But while the ocean north of the equator is closed by masses of land, and the northern equatorial stream is thus forced back upon itself, in the eastern portion of the southern part there is a movement of the masses of water toward the equator, and in the western a similar one toward the pole; in the center the sea, so to speak, is neutral.

Our chart shows that compulsory voyages become more and more infrequent the farther we go eastward from Asia, and, south of the equator, voyages with the trade wind are largely in the majority. This proves on one side that the accident of such a journey is most closely connected with the wind, and, on the other, that the continent of Australia is capable only in a small degree of transforming the relations of the wind sufficiently to produce the phenomena we encountered in the first district, when the huge masses of land in Asia exactly reverse the directions of the wind and currents.[2] In fact, the currents of the air

[1] Lesson believes that the Polynesian colonies in the New Hebrides were founded only in a limited degree by castaways; but we think that we have cited so many examples that the priority of the compulsory voyage is evident. There is no doubt that in addition to such incidents, intentional voyages must also have been made; otherwise the ethnographical picture of our islands would be even more motley than it is.

[2] The cause of the circumstance that we find no instance in our second district of a vessel being driven out of her course from the west toward the east appears to be that the inhabitants of the Hebrides, Solomon Islands, etc., undertake only voyages along the coast, as O. Finsch (Reise in die Südsee, p. 37) has pointed out.

and of the sea are much stronger and more steady in the Southern Hemisphere than in the Northern. Besides the aggregation of the islands in the Malay Archipelago, this is of special importance with regard to the western migration of the Malays, in the Indian Ocean. In our first district compulsory voyages are especially frequent; therefore the important inference follows that it is the modifications and complications of the mechanical conditions of the air and sea which carry people far out of their course into the ocean. It is also evident where we are to seek the point of departure of the Polynesians, namely, where the Oceanic islands are intertwined with those of the Malay Archipelago. The question would find but a doubtful answer, even if America on the west was closely wreathed with islands. But this is not the case and, besides, Revilla Gigedo, Galapagos, Juan Fernandez, and Salas y Gomez were, indeed, uninhabited. This fact speaks effectually against a migration from America across the ocean to our island groups.

If, in the examination of the first three districts, where boats are driven out of their course, the conviction has forced itself upon us that even the most remote Paumotu isles have received their inhabitants from the Malay Archipelago, in the presence of the Sandwich Islands still more comprehensive speculations open before our eyes. We see that the Hawaiians must naturally be mingled with Chinese and Japanese elements, and even in the Carolines this is not excluded. Perhaps herein lies the basis of the mental superiority of the inhabitants of these two groups over those of many others, and anthropogeography teaches that in reality it finds eastern Asiatic resemblances in the Carolines. If we look still farther eastward, we shall see that Bering Strait does not form the sole bridge between the Old and the New World. Migrations from Asia to America have undoubtedly taken place in more southern latitudes.[1] Nay, it even appears that the possibility of a migration backward from northwestern America to Hawaii is not excluded. With regard to South America, no material exists which could justify us in making deductions.

It seems to us, however, that the proof is furnished that the natural conditions, according to which we can judge the migration of the Malays across the sea, entitle us to group the original inhabitants of America with the Polynesians, Australians, and Malays in a single great family of peoples, the Mongoloid, who inhabited the coasts of two oceans, the Pacific and the Indian. The great capacity for journeying possessed by the Malays is an established fact. The power of separation which the Pacific Ocean has by reason of its width is diminished on the other hand, by the numerous islands; and as a continent favors commerce more when it is divided, so do islands when they are so numerous and so situated as the Oceanic ones. Here land and water

[1] We notice that, for instance, in the northwestern part of America, myths have existed which point to a migration across the sea; the Americans also have traditions of a western origin besides the one that they came from the north. (Chamisso: Bemerkungen.)

have exchanged their vocations; as, on the continent, man clings to the soil, here he is closely connected with the sea and the winds moving it—that is, he becomes a toy of the winds and waves. If by this time we have gained a comprehensive idea of the migratory capacity of the inhabitants of Oceanica, the natural result will be a perception of the inanity of the hypothesis which, to explain the dispersion of the peoples over the oceans, the Pacific and the Indian, makes a continent vanish,[1] instead of starting from the natural factors as they exist at the present day. Finally, the opinion that the people of Oceanica came from New Zealand is destroyed by merely looking at our chart.

Of course, no deductions of a positive character can be drawn concerning the individual acts of the migrations of the Oceanicans. The chart is still too incomplete, and besides, the voyages often change to the contrary direction. Only where numerous instances of vessels being carried in a certain course could be recorded are special inferences admissible. According to Kubary, the fact that the inhabitants of the Carolines were not infrequently carried to the Philippines, and that, in going there, they always reached the island of Samal or the southernmost portion of Luzon, is a proof that the northern equatorial stream breaks just at this point. On the other hand, inhabitants of the Philippines have never, so far as known, been carried to Pelew,[2] an evidence that the northeastern stream makes a circuit around these islands. The force of the current here must be very great, as it seems to conquer the first impulse of driving ships out of their course, which is most frequently the impact of the wind; for we have seen in the majority of voyages that they always occurred in consequence of storms. During long voyages, as in the case of those to America, the impelling principle, on the contrary, is to be attributed to the currents of the sea, for tempests are not sufficiently permanent. Even where the point in question concerns driftwood and other articles, the motive force is the current and not the wind, for the exposed surface is too small to permit the wind to wrest it from the dominion of the current: true, the wind acts indirectly through the stream all the more powerfully.

The aspect of our second group of castaways is a thoroughly characteristic one. The one-sided direction of the voyages leads us, with the previous deductions, to perceive distinctly a transfer of Polynesian blood to the Hebrides, etc.; but Viti must have been touched at each time on the way from Samoa to Tonga, and hence follows the constant intercourse between these last island groups.

Between our first northern district and the two southern ones is to be noticed a free space; there is scarcely a single instance of an accidental migration to record here; and the cause is not solely the scarcity

[1] Wallace afterwards explained the dispersion of animals in these regions without being obliged to assume a submerged portion of the globe.

[2] F. Ratzel: Völkerkunde II, page 341.

of islands in this region, but also the neighborhood of the zone of calms, which again affords a proof that the compulsory voyages and migrations of the nations across the sea are connected with the winds.[1]

We can now, with each distance traversed in a compulsory voyage as a radius, draw a circle around the point of departure and thus obtain an ideal conception of the migratory capacity of our islanders. It would be more in harmony with reality to unite in a curve the extreme points of voyages starting from a limited district, in order to obtain in the form of a plane a comprehensive expression of the mobility of the Mongoloid race. In the passages from Japan it is directly obvious with what remarkably mobile people we are dealing; this is a fact which ought not to be considered as trivial, which is frequently the case.

[1]Perhaps this circumstance explains why so few traces of Polynesian elements have existed between Samoa and the Moluccas. (See Meinicke in the Zeitschr. der Ges. f. Erdk., Berlin, 1869, p. 378.)

THE OLD INDIAN SETTLEMENTS AND ARCHITECTURAL STRUCTURES IN NORTHERN CENTRAL AMERICA.[1]

By Dr. Carl Sapper.

The ruins of northern Central America have for some time past enlisted the attention of large numbers of scholars, their scientific investigation having, in fact, begun more than a century ago. (Antonio del Rio in Palenque, 1787.) Nevertheless, we possess but few accurate accounts of old Indian towns and edifices, and a complete series of important new studies can not probably be expected for several years to come. Such are the accounts of ruins in Yucatan by E. Thompson and T. Maler, the thorough exploration of the ruins of Palenque by A. Maudslay, and of the ruins of Copan by an American commission, the plans of Comalcalco and Menché Tenamit, drawn by engineers of the Mexican Boundary Commission, and others, of the ruins on the table-land of Guatemala and Chiapas, although deserving as much interest as the majority of the lowland ruins; only very few have as yet been examined more thoroughly. I can recall here, besides Stephens's[2] descriptions, only the examination of Iximché by Dr. Gustav Brühl,[3] and thus I am compelled in my statements mainly to rely on my own observations. Now, although these are generally nothing more than the result of hasty visits and of rough sketches of the single places where ruins are found, I can not but hope that they may be of some interest, since I have made myself personally familiar with some examples of old Indian towns—settlements and edifices in almost every one of the separate ethnographic districts.[4] I must mention here that I have not examined these ruins with the eye of the artist or the architect, but as a geographer, desiring to establish the characteristic peculiarities of the shapes adopted in building towns and rearing houses, as

[1] Translated from Globus, Vol. LXVIII, Nos. 11 and 12, 1895.

[2] J. Stephens, Incidents of Travel in Central America, Chiapas, and Yucatan, London, 1854, page 313 ff, 331, 365, 383 ff.

[3] Globus, LXVI, page 213 ff.

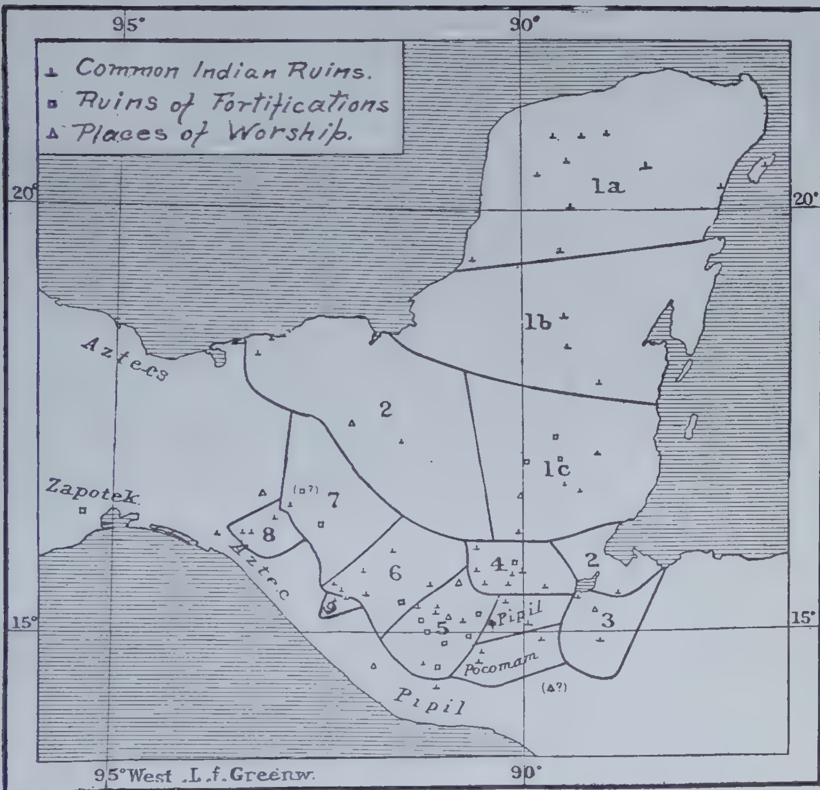
[4] In the territory of the Mije and Xinca tribes of Aztec and Zapotec origin I have observed only a few unimportant building ruins, and shall therefore pay little attention to them in this essay.

they differed in the various tribes, hoping that I might thus, if possible, secure some points of contact with the prehistoric migrations and the ethnographic connection of the tribes. I have also tried to show how far the architecture of men depends on the physical and orographic nature of the land and the character of the building material found in the vicinity wherever this could be shown. Under the influence of the above-mentioned views, I have paid but little attention to the ruins already investigated by more competent men, and in examining unknown or only imperfectly known ruins of settlements, I have confined myself to simple, rough measurements by the aid of the compass. The ground plans and sectional plans given here must, therefore, not be considered as accurate, but are merely intended to give a generally correct view of the disposition and the structure of the single buildings—more did not seem to be required for my purpose. As I have spoken elsewhere of the old Indian settlements of Guatemala and Chiapas, I need not return to them here. As, however, many ruins have not yet been investigated (like those of Chiapa, Tonalá, and Agua Escondida in Chiapas; of Piedras Negras, Yaxche, and Jolomax in Peten; of Benque Viejo in British Honduras; of S. Jorge, Aguacatan, Sacapulas. Mixco, Chajul, Canilla, Mita, etc., in Guatemala), and as, moreover, many other ruins have probably never yet been discovered, my material must needs be very imperfect, and the results I have obtained will have to be completed and reexamined, I shall therefore limit myself here to what is most important.

1. THE DISPOSITION OF OLD INDIAN BUILDINGS WITHIN THE SETTLEMENTS.

All the Indians of northern Central America have in earlier days lived, as they still do in our day, in wooden huts covered with grass or palm leaves, and more durable edifices were raised only for purposes of worship or of warfare, perhaps also to serve as homes for the highest spiritual and other dignitaries, in which cases earth and stone, and in times of higher refinement, even mortar, were employed. Of such only ruins are in existence, and they will therefore form the principal subject of this work.

The fact that in our day the majority of Indians live in remote regions, far from Spanish influences and scattered in separate homes, or in small clusters of houses, would seem to justify the presumption that a similar system may have prevailed in pre-Columbian times. Nevertheless, the Indians had besides, in those days, larger centers of population, such as surrounded their places of worship, within carefully fortified localities, or their royal residences, the salines, gold washings, and the like. It must be borne in mind, however, that these centers of population held only at fixed times larger numbers, as at times of religious festivals and devotional meetings; the fortresses only in times of war, the salines in the dry seasons, when alone salt could be made,



DISTRIBUTION OF STYLES OF BUILDING IN MIDDLE AMERICA.

1. Maya style; 1a. North Yucatec type; 1b. South Yucatec type; 1c. Peten type; 2. Chol style; 3. Chorti style; 4. Vera Paz style; 5. Quiché style; 6. Mame style; 7. Tzendal style; 8. Chiapanec style; 9. Motozintla style.

etc. During the larger part of the year it is probable the majority of Indians, and even those who owned a house of their own in the towns, lived in the country in simple huts, surrounded by their cornfields, as the case at this day in parts of Alta Verapaz. It was only the Spaniards who led the Indians to congregate in real towns and villages; and as an evidence of the strangeness which this mode of life had for them, it may be mentioned that many tribes of the Maya family never had a word in their language for this idea, and hence adopted for it the Mexican designation "tenamit". Only in Yucatan a stronger tendency to concentrate seems to have prevailed from of old, as the people there were forced to do so by the small number of permanent ponds (aguadas), of caves through which rivers were passing (cenotes), and of real springs.

The true nature of old Indian population centers can only be guessed at, since not a trace has survived of what constituted the principal part of a town, or that which was inhabited by the poorer classes who dwelt in mere huts. It is true the Spanish conquerors tell us much of streets and squares, but the actually existing ruins only show that squares, often very extensive, did exist; that in many towns they were exceedingly numerous and beautiful, but streets, in the modern sense of the word, I have never been able to find. Only at Iximché and in a few religious structures (Sajacabaja, Pasajon, S. Isídoro), have I found indications of such a design. Generally it is noticed that the ruins of the principal buildings (tumuli and stone structures) show no definite arrangement. A similar state of things exists even now in many Indian villages which have never been subjected to the Spanish rule of straight streets, intersecting each other rectangularly. They show nothing but a confused conglomeration of separate houses, with crooked and much intersected ways between them, but with no streets in our sense of the word. As the church, with its open square around it, now forms the center of these villages, it may be that the groups of public buildings may formerly have also formed, as it were, the kernel of similarly shaped settlements.

The old Indian towns of Guatemala and Chiapas have certainly, in ordinary times, harbored no very considerable population, for the space lying within the fortification line is generally very confined, and it is highly improbable that outside of this line other parts of the town should have been added, since such a proceeding would in war times have been as diastrous for those who lived outside as for the fortress itself.

It may be argued, on the other hand, that the older Spanish writers have left us very minute descriptions of many old Indian towns, but I must confess that I am very skeptical as to their accuracy in such matters. They seem to have indulged with great pleasure in large numbers, feeling sure of not being contradicted. Thus, Fuentes tells us that the chief commanders of the Quiches, Tecum Uman, in the year 1524, had

drawn 72,000 warriors from the capital, Gumarcah (Utatlan), alone, and the royal palace of Utatlan was said to have been 728 steps long and 376 steps wide. If we now recall these astonishing numbers in the light of the ruins of Utatlan, we can hardly keep from smiling, for the habitable surface of the real table-land of Utatlan is not quite 100 meters long, and would, therefore, at best not be able to contain an edifice of dimensions like the above mentioned. In order to be quite certain about this question, I measured the plateau by walking along the edges, when I visited the ruins in August, 1894, with my brother Richard, but I had not the time necessary to measure the buildings also. We agreed, however upon the fact that the principal court of the so-called palacio is only 100 yards long and 60 yards wide, and that the disposition of the surrounding buildings is almost identical with that of the so-called Resguardo. (I have inserted in the plan of the site (fig. 10) the place of the most important buildings from memory, because I subsequently saw that the plan in Stephens's Incidents in Travel, page 235, gives an erroneous impression.) These ruins have, moreover, since Stephens and Catherwood visited them, suffered much from dilapidation, mainly by the fault of diggers for treasures, who foolishly turned the whole plateau upside down.

It might, to be sure, be assumed that the table-land of Utatlan contained only the palace of the ruler with the accessory buildings and the temples, while the rest of the city might have covered the surrounding plain. In fact, there are at some distance from Utatlan a few tumuli rising in the plain which might be considered detached forts, built to protect the parts of the town in which the poorer people lived. But the Spanish writers say nothing of such an outer town, and the surface of Utatlan is no smaller than that of many other Indian fortified places like Saculeu, Comitancillo, Iximché, and others.

The nature of old Indian centers of population differed, of course, according as the settlement was made principally for defense or for the performance of religious worship, or merely for the maintenance of a king or a prince. In the table-lands of Guatemala and Chiapas, where a number of warlike peoples and independent hostile tribes of one and the same nation dwelt in close proximity to each other, the fortified character of their buildings naturally prevails, and they usually contained also the palaces of their rulers, and the temples of the deities.[1] Nature here offered in abrupt eminences, which were entirely or partially severed from the adjoining table-land by deep ravines, or on mountains with a level plain on their summit, places that could easily be defended and were really used for that purpose by the Indians. In building towns here, where nature had limited the space, the builders

[1] At times the princes also lived in open towns which they abandoned at the outbreak of war, withdrawing into near fortified places, as in the year 1525 Caibil-Balam, King of the Mames, retired at the approach of the Spaniards under Gonzalo de Alvarado from his capital, Chinạbhul (Huehuetenango), to the fortress Saculeu.

saw themselves compelled to crowd the structures as much as could be done, and this closely compressed disposition is hence characteristic of the ground plans of towns on the table-land of Chiapas and Guatemala.

As an example, I may here mention the well-known ruins of Toniná (that is, stone house), of which, however, I have only drawn the upper part (fig. 8a). The mass of the ruins lies upon a narrow ridge of hills, which in the direction of Toniná Creek, terminates the principal buildings (shown in fig. 8a) at the eastern end of the same. Already, below in the plain, considerable artificial hills are found. Then we ascend four distinct terraces, also quite high and artificially produced, the second of which is tolerably wide and bears some cross tumuli; and thus we reach at last the fifth, with the palacio (stone house **E**), which since Stephens's visit has evidently suffered much. Higher up still stand the two great pyramids. All the buildings are closely crowded to save space and evidently mainly intended for defense.

In Yucatan, however, where the supply of water was always a serious question, and where nature, moreover, had not provided such easily defensive localities, the principal buildings are much more freely scattered about, and some of them might have served for defense. But the whole arrangement is such and the decoration of the outer walls so profuse, that these towns must rather be looked upon as places of residence for their princes and high priests than as fortified places. It is true that I know only a very few such settlements in Yucatan, but if I may judge from Charnay's statements and from the still unpublished plans, drawings, and photographs of Mr. Tompson, in Merida, a like scattered disposition seems to prevail elsewhere as well as in Uxmal or Tzibinocac.

The southernmost Maya buildings, that is to say, the town ruins in Peten, like S. Clemente, and especially grandiose Ticul, show, on the other hand, clearly that they were intended for fortifications. The crowded position, the variety of isolated buildings, and the arrangement of many around a court, each one of which formed a new center for defense, prove this beyond all doubt. In spite of Mr. Maudslay's careful researches, we have as yet no really complete account of Ticul, and I was unfortunately unable to trace the ground plan of these grand old town ruins, which are slumbering here in the shade of primitive forests. I can only say that here may be seen a whole series of easily defensible courtyards, which in part lie in the form of terraces one above the other, while in the vicinity of the principal court, surrounded by magnificent buildings of stone, a number of steep, defiant pyramids arise, each bearing a grand stone building on the summit.

Much simpler and less important, and on that account also much more easily understood, are the ruins of S. Clemente (fig. 9), which had long remained unknown, concealed as they were in the forest, although they were within 200 yards of the riding path from Peten to Belize. The ruins cover a somewhat long hill, over which the buildings were so scattered that they formed a number of courtyards or squares,

almost everyone of which might have been most easily defended by itself. The courts B and C are on the same level, while the square marked A is one story higher, and the square D, separated from A by a narrow ravine, lies perhaps 4 meters higher. The stone houses I and II show on the outside only a smooth wall, at the foot of which begins a sheer precipice. The rooms in I and II are accessible from it, but the stone house III has its doors of entrance on the south side, now sadly in ruins, from whence they can easily be reached across a steep parapet. The upper plateau of III continues eastward at the same height, so that the continuation (IIIa) viewed from B looks two-storied, until, at the end of the edifice, it becomes once more one-storied. A narrow passage leads from the southwestern corner of B through IIIa to C. The western termination of B is formed by a wall, which rises as high as the square A; the eastern and northern ends consist simply of stone walls, and in the same way the eastern and western terminations of C and E. The walls 4 and 5 are built of cut stone and 3 to 4 meters high. On top of the rampart 9 a small much-decayed stone house is standing. Between C and D two tall, strongly-built stone houses are seen, each of which contains but a single room, open to the north, upon high artificially modified eminences. What is very remarkable is that at the foot of the hill, looking toward the northwest, a round hole has been found, barely large enough to let a man pass through. This leads to a subterranean story below, which I, however, did not dare to examine, as I had neither a rope nor sufficient light.

In the former Chol territory also similar connections of houses seem to exist, built in the shape of terraces side by side (e. g., Las Quebradas). Copan, also, otherwise in its disposition perhaps the most remarkable creation of Indian architecture, shows certain features of the same system.

The ruins in southern Yucatan are inferior in extent to those of the Maya territory. They often display the clearly pronounced character of fortifications, walled-in courtyards on high hills (as in Ixtinta, fig. 2) or extensive stone walls, or buildings on high passes, as upon the height of Caca de Xkanja, which may have served for the defenses, but may also have been used by travelers for the offering of prayers and of sacrifices (fig. 3). At all events, the type of fortified places is less pronounced here than in Peten. The buildings are less crowded, and the houses, built of stone, show much more careful, almost artistic, treatment of the outer walls. On the other hand, the structures are still not quite as much scattered as in the towns of northern Yucatan, and they lack the ornamental sculptures of the latter, so that the ruins of southern Yucatan occupy an intermediate position between the edifices of northern Yucatan and those of Peten.

In like manner we find in Menché Tenamit certain features which connect Tical with Palenque, and Toniná recalls in its buildings the towns of the lowlands, but follows in the arrangement entirely the habits

. Fig. 1.

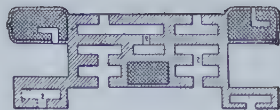


Fig. 2.

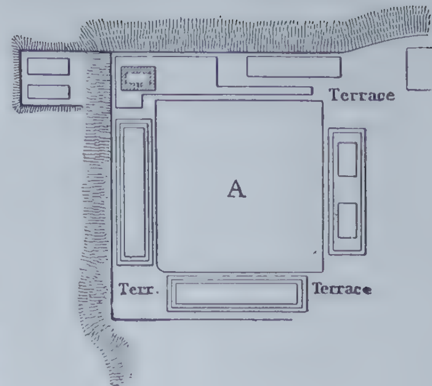


Fig. 3.

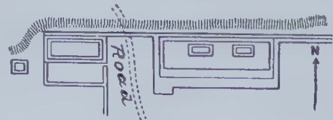


Fig. 4.

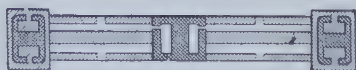
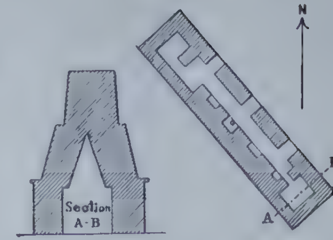


Fig. 5.



a b

Fig. 6.

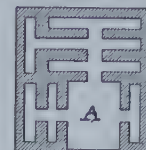
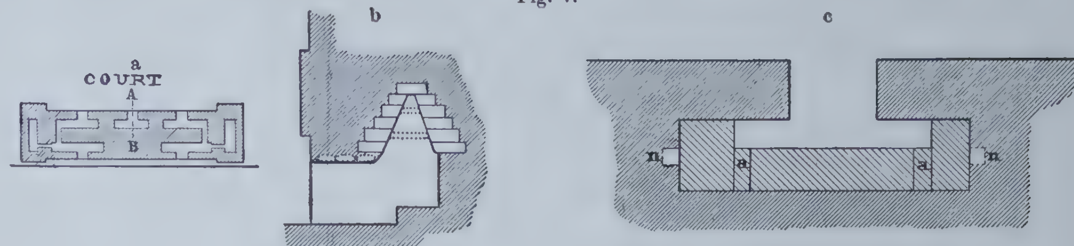


Fig. 7.



INDIAN SETTLEMENTS IN CENTRAL AMERICA.

FIG. 1.—Stone house, Ixtinta, Yucatan, 1:1600.
FIG. 2.—Fortification near Ixtinta. Yucatan, 1:1600.
FIG. 3. Building in Caca Xkanja, Yucatan, 1:1600.
FIG. 4.—Stone house in Tz'ibinocac, 1:1600.
FIG. 5a.—Cross-section of the principal temple of Menché Tenamit, 1:1800.
FIG. 5b.—Plan of same, 1:1400.
FIG. 6.—Plan of stone house in Tical (Peten), 1:1800.
FIG. 7a.—Stone house in Tical (Peten), 1:1600.
FIG. 7b.—Cross-section of the middle chamber of a stone house in Tical (Peten).
FIG. 7c.—Plan of same.

of the tribes on the highlands. There can be no doubt that the culture of a nation in northern Central America has always had its influence on the neighboring tribes, and thus we notice frequently, especially in frontier districts, features which remind us of the puculiarities of the architecture of adjoining districts. The isolated western court of Chama presents very clearly the type of Verapaz, while the eastern buildings remind us more of the Chol buildings, and thus also the ruins of Pueblo Viejo, whilst the nearly adjoining ruins of Chacujal, which probably once formed part of the whole, are entirely original.

In Verapaz we know only of small ruins of edifices, which in their simplicity contrast strikingly with the more complicated disposition of buildings in the settlements of both the lowland and the highland districts, although they share with them the fundamental type of a courtyard walled in all around or only in part, within which ordinarily small terraced pyramids have been standing. We also know of fortifications attempted in Verapaz, such as walls closing a narrow pass (at Las Pacayas), or mountain summits fortified or rendered inaccessible by piled-up masses of stone, e. g. Yaltenamit. As I have not examined the few remains of settlements which I know near Elbarrizal and Guatemala, I am not able to state whether the ruins within the Pokomam territory bear the Verapaz imprint or the character of the highlands.

Old Indian establishments for purposes of worship have been comparatively rare (e. g., Kalamté) and they also (as, for instance, Sajacabaja, Copan) were at the same time arranged for defenses, as of course the temple buildings with their walled-in courtyards and their terraced pyramids furnished groups of buildings that could easily be defended. Palenque I consider, with Charnay, a city for priestcraft and higher culture, also Quiriguá and the ruins on the Rio de la Pasion, where F. Artes in 1892, commissioned by the Guatemalan Government, obtained photographs of the monoliths and exhibited them at the Chicago Exposition.

A survey of the ruins within the Maya territory, as far as they are known to us, convince us that everywhere the fundamental type of inclosed courtyards reappears. In the highlands of Chiapas and Guatemala the disposition of the buildings is compact, since the buildings bore mainly the character of fortifications, and on that account localities were chosen which were naturally already confined, such as ravines, sudden precipices, etc. In Peten also the buildings are much crowded, evidently on account of warlike events which then occurred, although on the whole the settlements in the lowlands are more open and without any signs of defensive works in the foreground.

In all Maya ruins the buildings are, if not uniformly, at least very generally, built so as to face a certain direction; among the lowland tribes, toward the cardinal points. In the Verapaz tribes and among the Quichés, Tzutuhiles, Uspantecos, Aguacatecos, and other highland tribes (the Tzendal group, Mame group, and Cakchiquel), the

buildings face more generally in intermediate directions, but always in such a manner that within each town one certain direction prevailed.

In eastern Chiapas I have seen at Mazapa and Motozintla certain ruins which differ from the Maya type, although the people there now speak Maya languages. Besides other peculiarities, the absence of clearly defined courts must be noticed and the long drawn out character of the general plan (see fig. 11). Quite near by, at Chimalapal, I saw from a distance old Indian settlements, with clearly defined courts of the Maya type, facing the cardinal points (fig. 13).

In the Chiapas territory no such clearly defined courts as the Mayas have can be found. The courts, if at all existing, are not completely walled in, the buildings do not seem to face any one direction decidedly, but to be scattered about without any rule. The choice of locality, however, and walls evidently built for defensive purposes, show clearly that the builders intended to give to the whole the character of fortifications.

In western and southern Chiapas, in Soconusco and southern Guatemala, I found but few old Indian settlements, and those I did see were so completely ruined that I was not able to discern any striking peculiarities.

In the territory of the northern Pipiles, in the upper Motagua Valley, and in lower Verapaz, I have frequently seen traces of old Indian settlements, but they were almost completely effaced and beyond recognition. The ruins near S. Agustin Acasaguastlan are long stretched out, resting in one direction on a mountain slope, somewhat like the ruins of Mazapa. They show terraces and half courts and always face the cardinal points.

2. SINGLE BUILDINGS AND GROUPS OF BUILDINGS.

I have above called attention to the fact that the Indians of northern Central America lived in the days before Columbus in straw huts, as they do now, and there is no reason to assume that they have changed since in the construction of their houses. There existed, therefore, in those days the same difference in building among the various tribes and groups of tribes as I have been able to see in the present time and to describe elsewhere.[1]

For the larger buildings, however, and especially for the substructure, other materials were employed which promised greater durability. Where civilization was still lagging behind, walls of earth and of stone had to suffice, or terraced pyramids were erected of the same material, and probably bore on the summit wooden structures adapted to the desired purpose.

The most primitive shape of these walls were probably simple walls

[1]Contributions to the Ethnography of the Republic of Guatemala (Petermann's Mitteil., 1893, p. 12 ff) and contributions to the Ethnography of Southeast Mexico and British Honduras (same journal, 1895, p. 177).

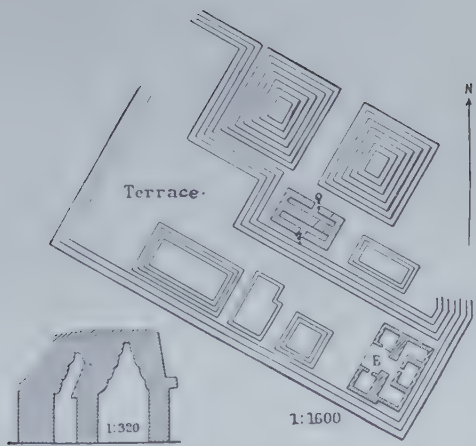


Fig. 8b.

Fig. 8a.

PRINCIPAL PARTS OF THE RUINS OF TONINA, NEAR OCOSINGO (CHIAPAS).

of earth which, as refinement increased, were incased in a covering of stone. Frequently, however, the whole wall was built of stone, and even the terraced pyramids consisted only of a kernel of earth, sometimes containing stone chambers within, while a covering of stone on the outside gave to the building a suitable outward form and durability. This is the point of development where the majority of the buildings of Chiapas, southern Guatemala, and Verapaz remained stationary, and even among the Maya tribes, who are so much further advanced, similar structures are still met with. At this time the stones that form the outer case were either not cut at all or only roughly; really well-cut stone is very rarely met with in such structures. This depended, naturally, very largely on the nature of the stone found in these districts. In Alta Verapaz and parts of central Chiapas the material is an easily split dolomite or limestone: in the Chiapas and Mòtozintla districts granite prevails; in the districts of the Tzotzil and the southern Pipiles other eruptive stones of more recent origin, which the Indians with their extremely imperfect tools must have found very hard to cut. The same difficulty no doubt also accounts for the fact that we find in the highlands of Guatemala and Chiapas comparatively few sculptures in stone, and that wherever any are found the nature of the material on hand has been specially favorable. Andesite, of recent origin or disunited, has frequently been used for the purpose, more rarely sandstone or even limestone; for small articles sometimes argillaceous schist, but never dolomite. In proportion as the available stone material was less fit for building and sculpture the love of ceramics increased, and, to mention but one example, the Indians of Alta Verapaz remained far behind their neighbors in all that concerned architecture; but, on the other hand, they furnished pottery of such admirable good taste and true artistic skill that they do not seem to have been surpassed by any of the Maya tribes. This would lead to the conclusion that architecture is not a standard by which we can measure the culture possessed by a people, because the absence of suitable material may easily interfere with their development and force their artistic predilections into other channels. Nor must it be forgotten that architecture is fostered and improved in proportion as it is favored by a nation politically and financially powerful. This seems to have been much less the case in Alta Verapaz than in Yucatan or in the highlands of Guatemala.

Edifices consisting merely of earth and of stone, simply piled one upon the other, are generally found in a lamentable condition, and it is but rarely possible to trace the outlines of such buildings accurately. The same difficulty applies to the nature of the steps which are almost always found on pyramids, and frequently on ramparts. As far as my researches go, the ground plan is generally square, rarely (by cutting off the corners) of five or more sides, but in spite of these variations, in the upper part of the buildings, square once more. Round foundations

I have never been able to trace with any certainty; a careful investigation led me in almost every case, even in apparently round or rounded-off structures, to trace the originally rectangular lines. The steps in the Maya buildings seem always to have been produced by an alteration of horizontal with perpendicular or nearly perpendicular planes; they are at the same time usually of the same height and depth. A very striking difference appears, however, in the structures of the Chiapas and Mòtozintla tribes, as they ascend sideways and leave only a small space horizontally open (fig. 11a). It is possible that this peculiarity betrays a certain dependence on the building material, as the rolling, rounded-off bowlders of granite which abound in that region can not very easily be piled up perpendicularly, and hence the building would acquire greater durability by steps ascending in a side wise direction. However this may be, the fact is that the method of building here differs essentially, and I feel justified in concluding from it that the districts of Mòtozintla and Mazapa, where now Maya idioms are in use, were formerly inhabited by a race of foreign origin. What race of men this may have been I can not even guess; I only believe that they could not even have been Chiapas, partly because the buildings in the Mòtozintla district seem to be more carefully arranged than among the Chiapas and partly because in front of several tumuli in Masapa and Mòtozintla (fig. 2, A, B. and C) carefully wrought pavements of flat granite tiles may be seen, such as I have until now never met with in the Chiapas district.

When we meet with perpendicular or nearly perpendicular walls of cut stone we may assume that this indicates a higher style of architecture, even though these walls may be erected without the aid of mortar. Such buildings are met with here and there, as in S. Agustin Acasaguastlan, frequently also in towns, where already stone houses are found standing, e. g., the stone tumuli 4 and 5 in the court C of the ruins of S. Clemente (fig. 9). The most remarkable of such edifices are those of Chacujal (Alta Verapaz), where primitive argillaceous slate, carefully carved on the outside, has been employed without any kind of cement for the purpose of raising perpendicular or very steep walls, and which bear on the upper platform a kind of parapet. The inner kernel of these walls consists of rounded-off river shingles. I have never found this same method of building anywhere else.

Still greater progress in architecture is seen in those structures on the high table-land of Guatemala, in which the stones forming the walls are held together by an abundant use of mortar. Mortar is, by the way, also found elsewhere (e. g., in Alta Verapaz), but not to such an extent that its use should have essentially influenced architecture. Even in Iximché, mortar seems to have been but of secondary importance. In Kalamté and Comitancillo, in Utatlan and Saculeu, however, many edifices consist simply of walls, and in order to secure steps these walls were erected perpendicularly; but where higher walls had

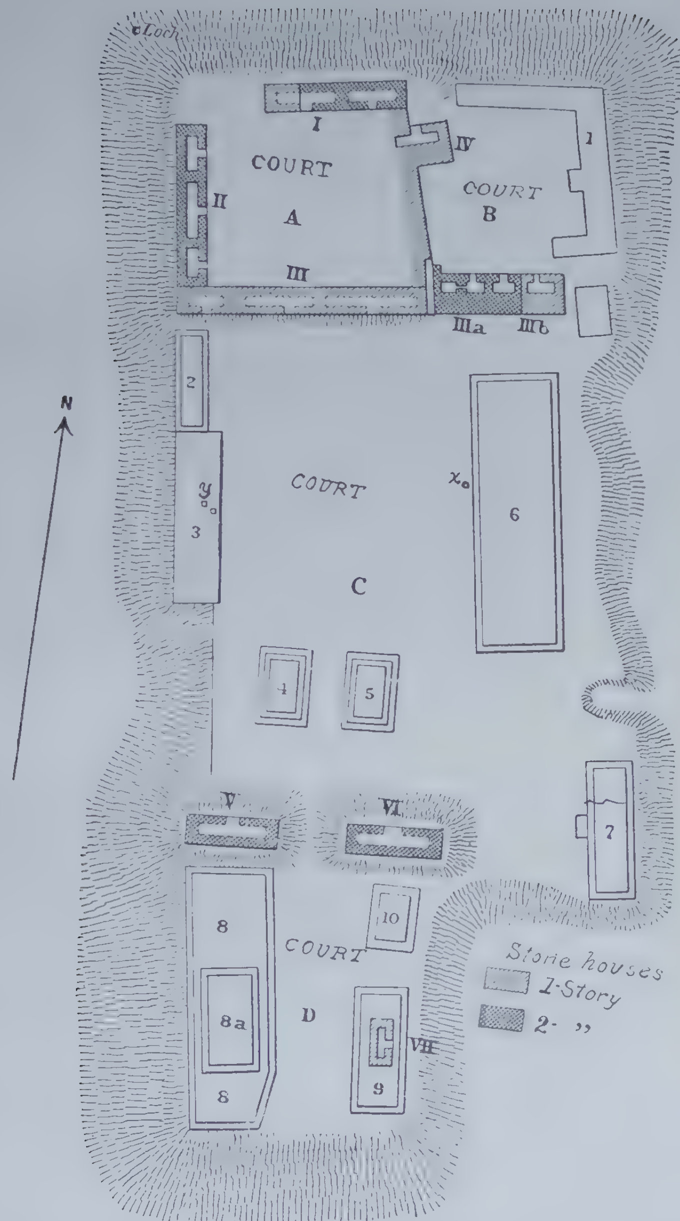


FIG. 9.—RUINS OF SAN CLEMENTE (PETEN), 1:1600.

to be raised without steps they were erected with a steep inclination, and separate staircases led up to the platforms. And it was the same with terraced pyramids that had especially high steps. A casing of smooth mortar formed the outer covering of these walls. Similar applications of liquid mortar formed the floor of the more important places and of the platforms of tumuli. In Utatlan, even now and in spite of the general destruction of the buildings, traces may be seen of paintings on the walls, and on some of the platforms the evidently grievously injured casing of mortar has been covered by a second and even a third application.

In the highlands of Chiapas, these last-mentioned architectural forms seem to be wanting, and the tribes of the Mam and the Quiché family appear therefore to be in some way technically opposed to the Tzendal group. Yet the highland tribes of Guatemala and Chiapas show not only in the manner of laying out their towns, but also in the erection of any definite temples, a surprising uniformity. We speak of a temple building consisting of two main structures which are alike, lie parallel to each other, and display on the side that faces the other a small, low terrace resembling a trottoir. Between these two edifices the temple court appears, deeply sunk, but spreading out wider beyond the two main buildings and almost altogether walled in, so that the shape of the court assumes a resemblance to a large letter H or I. From El Sacramento in Chiapas to Sajacabaja and Kalamté these H-shaped temple courts reappear with the same ground plan, but yet each one has its somewhat modified form. I insert a few slight sketches of such courts (figs. 12 and 10a).

It is very remarkable that in Iximché this kind of temple building is altogether wanting, or at least there are hardly any traces of such fundamental ideas to be discovered there, and yet the Cakchiquel have displayed in their architecture, which they have developed with great originality, no small correspondence with the same art among their neighbors. Thus we find in Iximché a rectangular, lengthy tumulus ("A" in Brühl's Plan of Iximché, Globus, vol. 66), the platform of which is walled all around, and this shows a courtyard which, relatively to the edges of the tumulus, is sunk deeply. The same manner of building I found twice in Sajacabaja and once in Saculeu, though here not quite according to the type.

It may be presumed that on all the edifices which have so far been discussed, unless they were intended to serve exclusively for defense, wooden huts must have been standing on the uppermost platforms, which either contained the images of their idols or may have served as reception rooms or residences for eminent personages. Among the lowland tribes of the Maya family, however, architecture has taken a step further in advance by substituting for these mere wooden buildings structures of stone with durable and habitable inner rooms. The fact that in Yucatan, northeast Chiapas, and in Peten well-stratified,

level limestone appears, has evidently caused and favored this improvement, as the appearance of finely grained limestone, resembling the slate of Solenhofen at Palenque and Menché Tenamit, must have caused the flourishing industry of relievo painting in that district. In the Chorti territory, where, near Copan, an easily worked building material appears in abundance (a decomposed, eruptive stone), architecture has progressed in a very peculiar manner, but the stone houses, while otherwise apparently of the same construction, appear less large and imposing than in the more northern districts. In the low plains of Tabasco (Comalcalco) the Indians (Chontal) have erected stone houses by the help of an artificially produced building material (bricks), beyond doubt in imitation of the stone houses of their eastern and northeastern neighbors.

Stone houses, so far as is now known, have not been built by any but the lowland Maya family in North Central America—that is, by the Mayas and the tribes of the Chol group (Choles, Chontales, and Chorties). These are the same tribes which even now differ from the other Maya people by certain peculiarities in their house architecture (advanced walls). Such stone structures as the Mam and the Quiché tribes possess are here entirely wanting, as are also the temple courts resembling the letter H.

In the territory of the Chontales only the ruins of Comalcalco, and in that of the Chorties, only those of Copan are known tolerably well. As I do not know the former from personal knowledge, and during my visit to the latter (January, 1894) only found a beginning made of a more careful examination, I can add nothing new to what has been stated before. I limit myself, therefore, in the remarks that follow to the observations which I made in the Chol territory in Peten and Yucatan.

The ground plan of almost all stone houses is rectangular, and wherever wings or other additions appear they also are rectangularly added to the main building. In Yucatan I saw several rounded-off edges on tower-like side wings (Ixtinta, Tzibinocac), and I thought it remarkable that these exceptions from the general rule should occur there alone, where the dwelling houses of the Indians uniformly show rounded-off ground plans.

These stone houses are in their simplest form narrow buildings with but one inner apartment, to which access is had from the side of a passage (e. g. the stone houses V, VI, and VII in S. Clemente). Where the buildings show any progress, the one inner room appears subdivided by niches, passages, and additions, and is approached by several doors of entrance on one side (fig. 5a, the principal temple of Menché Tenamit), or several separate rooms are found in the same stone house, connected with each other, but each having its own means of entrance from without—e. g. the stone houses I, II, and III in S. Clemente, fig. 9. If architecture has made still greater progress we

FIG. 10.—PLAN OF THE SURROUNDINGS OF UTATLAN, 1:18000.

find two or three rows of rooms, one behind the other, which are connected with each other and have exits, on one or the other of their longer sides (fig. 7). It is not my intention here to pursue the almost boundless variety of plans of stone houses at the various places of ruins; I only mention here that where architecture has progressed still further, side wings are found—added to the main building (barely indicated in fig. 7, Ticul, more clearly in the stone houses of Tzibinocac, fig. 4, and Ixtinta, fig. 1), or the building incloses a court partly (Ticul, fig. 6) or entirely (Palenque, Uxmal). In Palenque the front wall is sometimes reduced to a number of pillars by the frequency, the height and width of the door openings, so as to change the wide, outer room in its great length into a kind of well-lighted portico.

The stone houses of Toniná,[1] the only ones known to exist in the territory of the Highland tribes, are, as far as the ground plan is concerned, most nearly related to the structures at Palenque.

The outer walls of the stone houses rise either perpendicularly or they are steeply inclined, parts occasionally extend even beyond the foot of the walls. On the whole, however, the horizontal section through the building diminishes in proportion as it is made at a greater height—that is, the building grows smaller from below upward. The outer walls are partly shaped by a smooth layer of mortar (so usual at Peten), partly adorned with stucco (Menché Tenamit, a few houses in Ticul), partly ornamented with separate tablets, showing images or hieroglyphics (Palenque), or cased with a smooth covering of stone (South Yucatan), which in North Yucatan is adorned with sculptures. The substance of these buildings inside the casing consists, where no well-stratified calcareous schists are found, of bowlders and an abundance of mortar.

All around the edifice continuous cornices are seen, which produce the appearance of a building of several stories, as they occur at almost equal distances, one above the other. This impression is aided by the fact that the external divisions of the outside occur exactly at the place where the cornices appear. Thus one meets with buildings of one or four stories, though ordinarily they are only of two or three stories. Sometimes, again, certain parts of a stone house are higher than others, and when in this way (as in the stone houses of Ixtinta and Tzibanocac) the main body and the wings seem to be of different height, such structures gain a certain variety of forms which is pleasantly felt in contrast with the general uniformity of all Maya buildings.

The inner rooms of stone houses are small and rather badly lighted, since no daylight enters except through the door openings. Only rarely little low windows are found, which are pierced through the

[1] In Kalamté I saw the scanty remains of a small stone house, the thin walls of which, however, caused the presumption that these could not have supported a massive upper story, such as is characteristic of Maya buildings. It seems, therefore, to have been a different kind of construction.

outer walls, if they do not contain several inner rooms of the same house (Ticul, fig. 6). The upper closing of a room is brought about by the gradual approach of the longitudinal walls, till they are near enough to each other to allow the space between to be closed by a few flat, stone tiles. This reduction of space is produced by overreaching stones, each upper row protruding over the one below. The edges thus produced are smoothed over with mortar (e. g., in Toninà fig. 8b) or they are entirely concealed. Where more careful work was required, the stones were cut obliquely, so that when laid one upon the other they would show a straight-lined reduction (fig. 7b, in Ticul), and in Uxmal may actually be seen, in a few cases at least, a few slightly curved lines of reduction, convex or concave. Between the two walls which are thus treated to lead to a closing above there are commonly found some cross pieces of wood, generally zapote wood, which were meant to increase the durability of the structure, and perhaps in dwelling rooms, to suspend hammocks. Above the door openings, which are simply covered flat at the top, without any effort to approach the sides, strong cross beams, mostly of zapote wood, serve as supports; in Palenque and Menché Tenamit huge slabs of stone. Where the inner rooms are long and narrow, only the long sides are shortened; on the two short sides the walls go up straight and unreduced; but if the four sides do not differ much (as in Toniná), all are shortened in the above-mentioned way. In small and narrow passages the closing is brought about by horizontal slabs of stone. In Toniná a peculiar way of forming a ceiling is noticed as shown in fig. 8b.

The inner rooms of a stone house are generally of the same height. Staircases in the interior of houses, I have never seen—excepting the famous tower of Palenque—unless it be in the tower-like raised side wings of Ixtinta, where they only lead on the outside to the upper platform.[1]

The inner rooms of Maya stone houses are, as a rule, lacking in ornaments; only rarely wall paintings are seen (as in Chichenitză, Toniná, Tzibinocac), or stucco ornamentations (Toniná), or in separate niches relievo tablets and hieroglyphics (Palenque), or statues (Menché Tenamit). Most structures of this kind show their principal ornamentation on the outside. The outside of stone houses in North Yucatan are specially rich in sculpture adornments; and here the contrast of the architectural style with that of Mitla in Oaxaca (the Zapotec district) is most startling, for the above-mentioned edifices, which also differ fundamentally from the Maya buildings in the construction of their roofs and in the introduction of round pillars of stone have their principal adornment in the interior, while the external walls are left comparatively plain and unadorned. This great simplicity of the small inner rooms in a building which is on the outside almost too richly adorned, as is the case in the Casa del Gobernador at Uxmal, makes a

[1] Others have also been observed in North Yucatan and Copan.

Fig. 11.

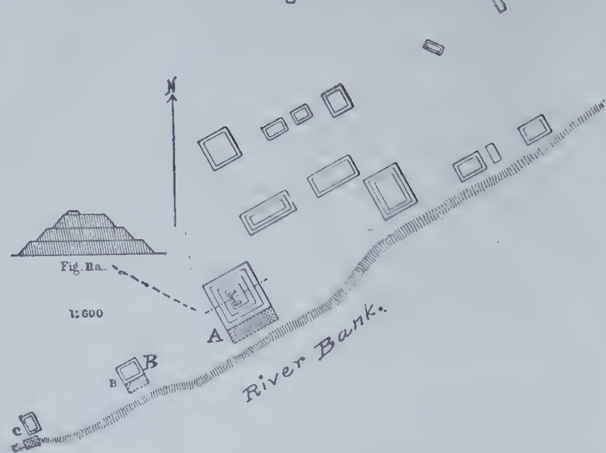


Fig. 12.

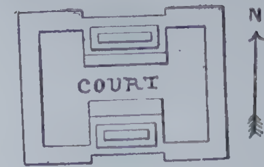


Fig. 13.

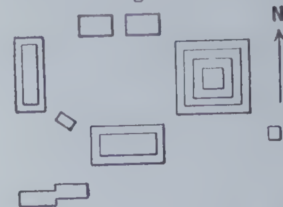


Fig. 14.

Fig. 15.

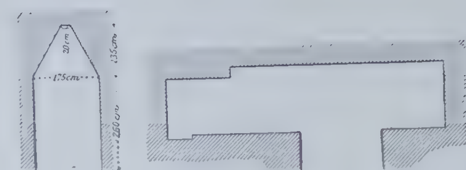
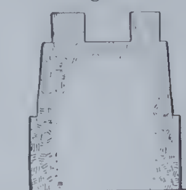


Fig. 16.



INDIAN SETTLEMENTS IN CENTRAL AMERICA.

FIG. 11.—Ruins of Motozintla (Chiapas).
FIG. 12.—Temple court near El Rosarita (Chiapas), 1:1800.
FIG. 13.—Ruins near Chimalapal (Chiapas), 1:1800.
FIG. 14.—Ruins near San Isodoro (Chiapas), 1:1600.
FIG. 15.—Section and plan of a chamber of Ticul, 1:1200.
FIG. 16.—Schematic section of a stone wall of Chacujal, 1:1200.

very peculiar impression upon the beholder and reminds him involuntarily of the narrowness of views which seems to be a universal weakness of the Maya family, who otherwise possess so many most attractive characteristics.

Besides the stone houses, several towns of Yucatan and Peten possess still another remarkable type of edifice—steep stone pyramids, which on their uppermost platform bear a somewhat long stone house.[1] I have seen these structures only in Uxmal and Ticul, and the four stone pyramids at the last-mentioned place were so entirely overgrown with forest trees and dense shrubbery that I could not obtain a clear view,[2] although I climbed up to the top of one with great trouble. The stone pyramid of Uxmal rises in two unequal terraces, over which a comparatively low, perpendicular terrace leads to the upper platform which bears the stone house. In the middle of one of the long sides (from the east) a very steep staircase with nearly one hundred steps leads to the platform. This kind of pyramid seems to be peculiar to the Mayas (in Yucatan and Peten) and to Copan, for in the territory of the Chol and the Chorti we find only the ordinary terraced pyramid, with perpendicularly ascending steps of equal height and depth. The same applies to the highlands of Guatemala and Chiapas, where it is true the steps occasionally seem to lose their original purpose and to assume gigantic dimensions (1 to 2 meters in height and depth), as in Saculeu and Toniná. In the two great pyramids of Toniná we notice, from the bottom to the uppermost small platform, six to eight lofty steps. These steps, however, being so very high, do not ascend perpendicularly (as at Saculeu), but at a great inclined angle. That Catherwood's Reconstruction of the Pyramids, in Stephens's Incidents of Travel (p. 384), is incorrect, is best seen from the northwest, where both show their best preserved side. I am sure I do not wish to blame Catherwood, but only to point out the great difficulties which arise at every such attempt at reconstruction. It is extremely difficult to form by means of decaying ruins a picture of former proportions, and often a mere glance from an accidentally chosen but favorable standpoint gives a clearer sight than a long study of the ruins themselves. To this must be added that the generally poor state of preservation of all such ruins has led almost everyone to add to this sketch or ground plan a number of reconstructions; my own very trifling sketches must not be considered final in any way. I shall be well content if I should have succeeded in giving my reader a tolerably correct idea of the old Indian structures in North Central America and of their great variety. An exhaustive description of old Central American architectures, which should enter into all details and state their peculiar manner of forming settlements, must needs be preserved for future generations, and I shall be satisfied if I may state here the conclusions which the available material has enabled me to form.

[1] Recently also found in Copan.

[2] A reconstruction will be found in Maudslay at the proper place, page 18.

3. COMPREHENSIVE REMARKS AND CONCLUSIONS.

The old Indian edifices of northern Central America display in various parts of this territory an unusually great variety both as regards the disposition and the construction of the single buildings. Upon closer investigation we find, however, that the structures of special districts show certain peculiarities which are common to all of them, but are not found in the structures of adjoining districts. These common peculiarities, however, apply only to general features, whilst we never meet with slavish imitation of a definite style of architecture. On the contrary, even within the boundary lines of a certain style there exists still an almost indefinite variety of disposition and outward formation among the Central American Indians. As the edifices in the neighborhood of a style of building often already show hints suggested by the peculiarities of a neighboring style, we may conclude from this that the Indians maintained among themselves a lively intercourse and possessed a great capacity for acquiring knowledge and taste from their neighbors. Everywhere we find the fundamental idea of walls and terraced pyramids, but in their erection many varieties of style at once appear. Unfortunately, I must here limit myself to the structures on the highlands of Guatemala and Chiapas, and to those of East Guatemala, Peten, Tabasco, and Yucatan. Within this district I think I may define the following styles of architecture:

I. The steps of the pyramids and walls are ascending. The buildings are not distinctly grouped around courtyards (squares).

1. Chiapas style: The buildings of a settlement are rather irregularly arranged.

2. Motozintla style: The buildings of a settlement show a tendency to face a certain direction. In front of many tumuli tile pavements are made.

II. The steps of the pyramids and walks are perpendicularly ascending. The buildings of a settlement face any one decided direction. The larger settlements show a part of their buildings arranged entirely or in part around an inclosed courtyard or square.

ARCHITECTURAL STYLES OF THE MAYA PEOPLE.

A. *Varapaz style.*—The settlements are mostly small. The buildings face the four cardinal points. Mortar was but imperfectly used. In Chacujal stone buildings with perpendicular walls, parapets on the platform.

B. *Architectural styles of the highland tribes.*—The settlements show a crowded disposition of their buildings. In the whole district temple courts shaped like H make their appearance.

(*a*) No mortar is used in the buildings.

1. Tzenal style: The buildings of a settlement are not arranged so as to face the cardinal points, but preferably intermediate directions.

(*b*) In many buildings mortar is used in erecting stone houses.

2. Mame style: The buildings of a settlement are generally made to face intermediate directions.

3. Quiché style: The buildings of a settlement face the cardinal points.

C. *Architectural styles of the lowland tribes.*—In many buildings stone walls, cemented with mortar, are found. Stone houses with habitable inner rooms. The buildings mostly face the cardinal points.

1. Maya style: At times steep pyramids. The door beams made of zapote wood.

1a. Peten type: The buildings of a settlement are closely crowded. Formation of many courts (squares). Character of fortification. The walls show a casing of mortar. Mostly unadorned houses.

1b. Type of South Yucatan: Transition type. The arrangement of buildings is less crowded. The walls of the stone houses are often incased in stone, carefully cut, but simple.

1c. Type of North Yucatan: The arrangement of the buildings is rather a scattered one. The outer walls of the stone houses are often richly adorned with sculptures.

2. Chol style: The door openings are generally closed above with level slabs of stone. The ornamentation of stone houses consists in stucco ornaments or in tablets containing images or hieroglyphics.

3. Chorti style: Very peculiar development of the pyramidical structure and of courts (squares). In Copan a steep pyramid.

The stone houses of Toniná belong to the Chol style, while the other edifices and the general arrangement follow the Tzenal style. The ruins are now situated in the land of the Tzenal people, but not very far from the line, since the nearest Lacandon and Chol settlements are hardly 30 or 40 kilometers distant, and it can not be absolutely asserted that Toniná may not originally have been a Toniná or a Chol settlement. However this may be, Toniná has always shown a mixed style, at all events borrowing from a neighboring style, so that I do not feel justified, by the occurrence of a single instance, to attribute the existence of stone houses to the Tzenal style.

The Indian edifices of northern Central America very frequently show a striking want of symmetry. The very simplest buildings, to be sure, are almost always symmetrical, because in their very great simplicity there was no scope for unsymmetrical arrangement. But the more varied single buildings and central structures, like great temples, show almost always an unequal development on the two sides from a middle line, and although the gradual development of architectural art led step by step to a better observance of symmetry, it is nevertheless curious to observe how, after all, only the very best edifices of Yucatan and Palenque ever attained unto full symmetry. It is true that frequently only mere trifles display a want of this kind, but on examining a building of this kind, or even a ground plan, we always feel as if this

unsymmetrical arrangement were not so much the result of negligence as of a set purpose. And how capriciously even the inner rooms of the stone houses may be differently adorned on both sides of the entrance can be seen in the plan of a room in Tical (fig. 15). Even the richly ornamented inner room of the principal temple of Menché displays in the different positions of the entrances relatively to the most external side apartments constant neglect of symmetry.

(42) In this connection it may be noticed that the Indians of the Maya family showed the same tendency to an unsymmetrical cultivation of development of the individual members in their musical melodies also.[1]

(13) These side apartments seem to have been used by the Lacondons mainly for their sacrifices, since it was in these rooms that I found, in 1891, most of their sacrificial vessels made of clay.

All the tribes which belong to the Maya family[2] have certain peculiarities in their manner of building, and it is of the utmost importance that within the territory they at present occupy, and according to the limits of the knowledge which we at present possess, no buildings are known to us which betray a foreign style, except only the few at Mótozintla, of which I have spoken above. This would justify the same conclusion which I also reached in studying the local names—that the Maya tribes have for a long time already occupied their present homes in northern Central America.

A comparison of the architectural features which all the Maya tribes have in common suggests also a certain conclusion as to the degree to which their architectural skill had raised among them before the tribe separated. This is a very low degree—walls and terraced pyramids of moderate size, facing a fixed direction, and frequently grouped around a court or square.

It appears, however, as if the lowland tribes had already parted with the primitive Maya people at a time when the Verapaz tribes (the Pocoman group) were still in close contact with the highland tribes, since their straw huts (dwelling houses) are in their construction perfectly identical, while the lowland tribes differ in having an advanced wall. At the same time the Chol and Chorti Indians, dwelling near by, still adhere to the rectangular ground plan of the highland huts, while Chontals and Mayas abandon this type in favor of rounded-off ground plans.

While the Verapaz tribes thus remained on a lower grade of architecture, the tribes of the highlands and the lowlands both developed the art in their own peculiar manner. Among the highland tribes, the Quiché and Mam group made great progress in architecture,

[1]Compare the New Journal for Music, year XI (1895), Nos. 7 and 8, and year XIII (1892), Nos. 22 and 23.

[2]I have, unfortunately, here to omit the Huastecs, since I have no information as to their buildings.

which the Tzenal group, however, did not share, while the lowland tribes, each in its most original manner, attained high success in the same art, no doubt largely assisted by the favorable stone material which they found at hand. In like manner the peculiar qualities of the outcropping stone no doubt led in the Chol territory to making relievo works, in the Chorti territory to monolithic sculpture, and in northern Yucatan to a sculptural adornment of their houses.

A very long time must, of course, have elapsed between the time when simple buildings were raised by the primitive Maya family and the days when the beautifully developed architecture of temples in Sajacabaja of original Copan pyramids, of excessively adorned stone houses in Yucatan, of defiant Ticul structures, and of harmoniously composed and ornamented edifices in Palenque began to show itself. Hence, we assume with certainty that each one of the Maya tribes here mentioned may have occupied their present homes for a more or less extended period of time, and that their architecture was developed only within this time. The influence of the surrounding stone material on this architecture may here and there become perceptible, and the locally limited origin, as well as the locally varying development of this architecture, will clearly show that any influence of Asiatic styles of architecture is absolutely excluded. It is true that so far the study of the architectural ruins has given no clew to the original home and to possible former migrations of the Maya family. I can, therefore, here only express the wish and the hope that future and more extensive studies, made on a broader basis, may succeed in establishing the views here suggested more firmly in determining the exchange of culture by comparing the architecture of neighboring races, and in thus providing a safe basis for prehistoric research.

PRELIMINARY ACCOUNT OF AN EXPEDITION TO THE CLIFF VILLAGES OF THE RED ROCK COUNTRY, AND THE TUSAYAN RUINS OF SIKYATKI AND AWATOBI, ARIZONA, IN 1895.[1]

By J. WALTER FEWKES.

I left Prescott, Ariz., on June 1, 1895, making my way with all possible dispatch to Old Camp Verde, and from there to the cavate dwellings, opposite Squaw Peak, 8 miles south of the post. After an examination of these troglodytic habitations, occupying a week's time, I followed the Rio Verde northward to one of its tributaries, Beaver Creek, examining Casa Montezuma, Montezuma Well, and neighboring ruins. Crossing the divide to Oak Creek, another tributary of the Verde, near Beaver Head, I camped near Schürman's ranch, where I remained a few days studying house ruins, fortifications, and aboriginal irrigation canals in that neighborhood.

Leaving all trodden roads at that point, my expedition penetrated into the Red Rocks, where a few days less than three weeks were consumed in exploration of that region. Later, I returned to Oak Creek, made a detour around the Red Rocks, over the Mogollon escarpment to Flagstaff, where I arrived on the last day of June.

Two days later I reoutfitted at Holbrook, Ariz., and camped at Awatobi on July 5. Three weeks were spent at that ruin, but owing to the defection of my Indian workmen, I was reluctantly obliged to prematurely suspend work there, and moved my camp to Sikyatki, where great good fortune awaited me. On the 29th of August I was again at Holbrook, where I disbanded my expedition at the close of the month.

I was accompanied by two paid men throughout the summer; one, a cook and driver; the other, a photographer. Two additional men were employed for a few days to assist in excavations at the ruins of the Red Rocks.

My force of laborers at Awatobi numbered eight, and during the excavations at Sikyatki fifteen, all Moki Indians, were employed. While in my employ they lived at the expense of the expedition.

[1]While the cost of this expedition was defrayed from the appropriation of the Bureau of Ethnology of the Institution, this preliminary account seems to possess such popular interest that it has been deemed desirable to give it early publication here.

My force of laborers at Awatobi numbered eight, and during the excavations at Sikyatki fifteen, all Moki Indians, were employed. While in my employ they lived at the expense of the expedition.

I was joined at Sikyatki by Mr. F. W. Hodge, of the Bureau of American Ethnology, who rendered most valuable aid, and by Mr. James S. Judd, a volunteer, who contributed much to the success of the expedition. Mr. G. P. Winship, whose translation of the Spanish text of Castañeda's account of Coronado's expedition is about to be published by the Bureau of Ethnology, was a guest of the expedition at Sikyatki for two weeks.

The objects collected during the three months will increase the Museum catalogue by 966 entries, of which nearly 500 represent specimens of the finest pottery, fully two-thirds of which are decorated.

In addition to objects collected, the expedition took many photographs, made copious notes, and prepared a few ground plans, necessarily rough, as material for an extended systematic report. The following pages give a fair idea of the scope and character of the work accomplished, but its significance in all its bearings can be adequately presented only by an elaborated discussion of the subject.

SCOPE OF THE WORK.

The general plan of my field work in Arizona during the summer of 1895 was an examination of cliff dwellings and other ruins of the valley of the Rio Verde and an archæological exploration of two ancient ruins in the old province of Tusayan, the ancestral and present home of the Moki Indians. The reason which determined my choice of the Verde Valley ruins as a field of investigation was a wish to obtain archæological data bearing on certain Tusayan traditions. A study of the ritual and mythology of these people for several years had familiarized me with a rich collection of folklore consisting of tales of cosmogony, heroic stories of supernatural beings, and migration legends. These stories, existing in many variants, are the sole histories which the Mokis have, and are transmitted verbally from one generation to another. They have come down to our day from a remote past, oftentimes highly embellished, doubtless more or less modified in transmission, but presenting the only material which is available, so far as records are concerned, of their origin and migrations previously to their settlement in their present homes. The legends of cosmogony are manifestly outside the realm of scientific verification, but migration stories are evidently of much greater import to the student of archæology. These stories are repeated, notwithstanding their variations, with an exactness which is highly suggestive of truth in their general character. The old story-tellers recount with detail the places where their ancestors halted in their migrations, and declare that they built homes or villages near certain springs, mountains, or in well-known valleys, where, they declare, the visitor may still see the ruins. Evi-

THE RED ROCK COUNTRY.

dently here we have an opportunity to test the legends by archæological research.[1] We can visit the sites of villages claimed by the ancients and find out if the evidence supports the legends of the present Mokis, or whether the stories are true or false. The present article is therefore a report on an attempt to apply archæological methods to the verification of legendary histories, which was the main thought in mind when I entered upon my explorations in Arizona.

The Tusayan villagers are divided into several phratries, each composed of a number of gentes. One of these phratries is called the Patki or Water House people, whose legends are very definite that they came from the far south, which is called Palatkwabi, Red Land. The situation of this mythic land is a matter of conjecture, but it was thought that an examination of the country at or near the headwaters of the Rio Verde and its tributaries west of south from the present villages of Tusayan and due south of some of their ruined towns might shed light on this tradition.

A complemental fragment of Pima folklore in southern Arizona connects the numerous ruins of the Gila Valley, of which Casa Grande is the best known, with the ancestors of the Tusayan Indians; and as the tradition which has been mentioned declares that their ancestors came from the far south, we have a correspondence in traditions which, to say the least, is highly suggestive. That archæology might give valuable information on the theory of former connection of northern and southern prehistoric peoples of Arizona had long been my conviction, and was the main influence which led to the choice of this field for exploration, of which this report is a preliminary record.

THE RED ROCK COUNTRY.

An examination of a map of Arizona will show that one of the most natural pathways or feasible routes of migration between the southern Arizonian prehistoric peoples of the vicinity of Casa Grande and the northern, north and south, would be along the valley of the Rio Verde. Oak Creek, a tributary of this stream, rises in the neighborhood of ruins whose inhabitants were ancestors of the Tusayan Indians, and empties, through the Verde, into the Gila not far from the great ruins which mark the center of the flourishing aboriginal population of southern Arizona. Along the banks of this stream was a natural highway, which presents favorable conditions for migration. My problem was to examine this roadway to see whether or not there are archæological evidences of former habitations.

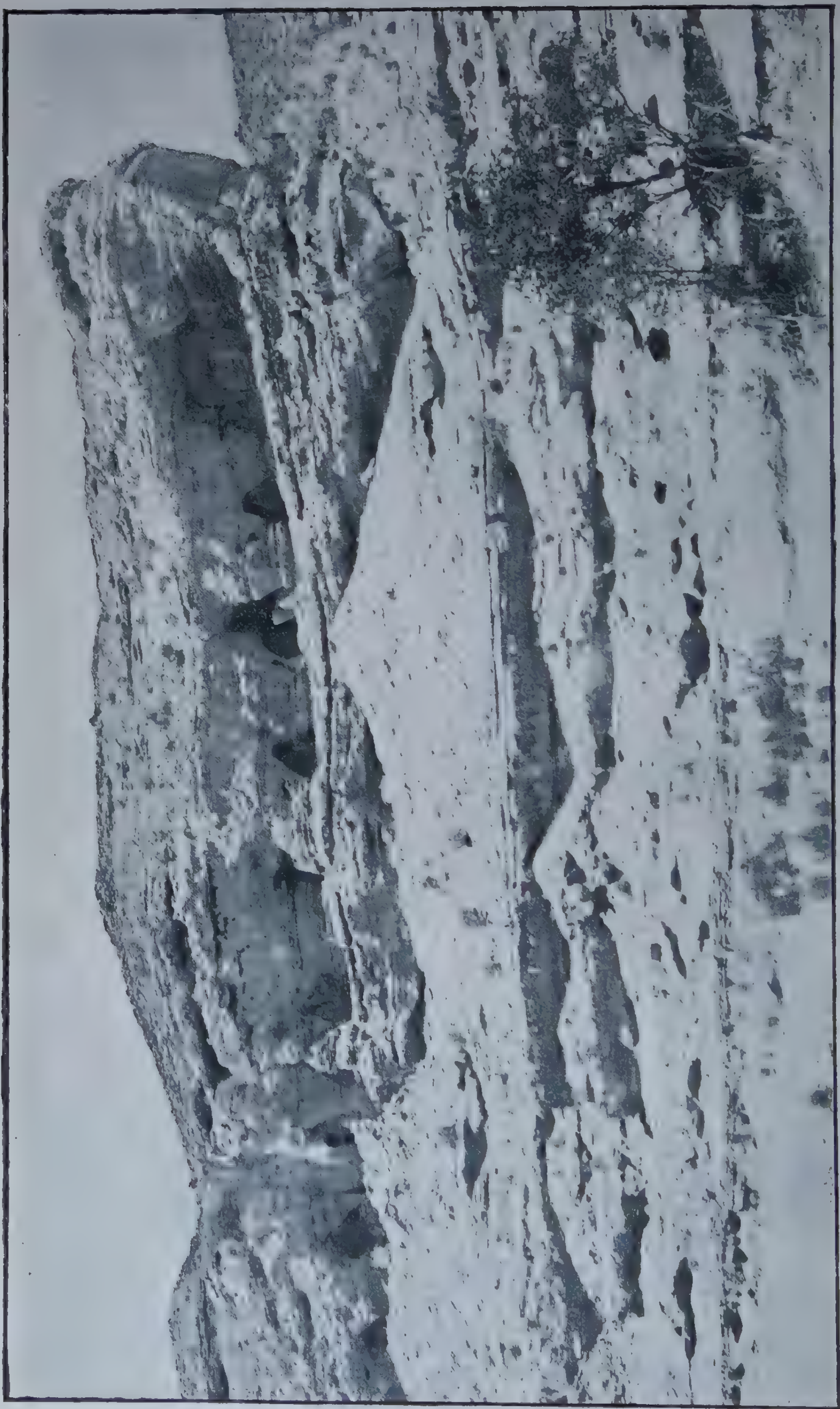
Exploration of the antiquities of this region had gone far enough to

[1] As this paper is about to go to press (September, 1896), reports have been received from Dr. Fewkes regarding his recent excavations at the prehistoric Moki pueblo of Homolobi, near Winslow, Ariz., which fully bear out his statement of nearly a year previously and testify to the accuracy of the native traditions concerning the settlement of the Moki at the place named prior to their occupancy of the present villages of Tusayan.—EDITOR.

prove that the banks of this river and the walls of neighboring mesas were formerly the sites of many and populous towns. From its junction with the Gila to Montezuma Well, several miles north of Old Camp Verde, there had been described a succession of ruins indicative of former habitations. But Montezuma Well is a long distance from any Tusayan ruin, and between it and the Moki country is situated the rugged, untrodden land called the Red Rock country. There was, in other words, a break here in the almost continuous series of ruins from Tusayan as far south at least as the large forgotten towns of the Gila Valley. At either extremity the chain of aboriginal dwelling places was unbroken, but middle links were wanting.

All conditions imply former habitations among these untrodden fastnesses of the Red Rocks, and the existence of former villages had been vaguely reported by ranchmen. So far as the evidence went, these reports confirmed my suspicions, but no archæologist had examined the ruins and their character was problematical. The color of the rocks of this country, as implied in the name, fulfilled the Tusayan legend of Palatkwabi, the Red Land, and it was situated directly south of ancient Tusayan ruins. When the opportunity came to me to conduct an archæological expedition, I determined to penetrate into this broken, inaccessible region and discover whether it, too, possessed ruined villages related to those of the Rio Verde and the Tusayan province, thus completing the chain of aboriginal abandoned towns from the Gila Valley to the Moki country. It remains for me to show in this report that the discoveries which were made by me in this region prove that it was in old times the site of a flourishing population, and to point out that the character of the people, as indicated by archæological evidences, bore many similarities to those of the ancient people of Tusayan.

Having demonstrated that the known ruins of the Verde Valley were continued into the Red Rock country, it was desirable to compare them with those at the two ends of the series—the Verde ruins and those of Old Tusayan. This necessitated reexamination of ruins already known, near Camp Verde, and a careful exploration of ancient Tusayan towns. The former work was carried on in the early part of June; the latter in July and August. I entered the Verde Valley by way of Prescott and the military post, Camp Verde, following the river down to Squaw Mountain, and examining groups of cavate dwellings, cliff houses, and ruins in the open country as far as the Red Rocks as the three representative types of the former housebuilders of this interesting valley. I then turned north and penetrated to the southern border of the Red Rock country, from which I continued to Flagstaff. The two Tusayan ruins which I chose as sites of my work were Awatobi and Sikyatki, the former a historical pueblo destroyed at the close of the year 1700; the latter a ruin deserted before the advent of the Spaniards in 1540.



CAVATE DWELLINGS (VERDE VALLEY).

The reader will notice that I accept without question the belief that the so-called cliff dwellers were not a distinct people, but that the cliff houses were results of special adaptation to environment of a race who sometimes excavated cavate dwellings or built houses in open plains. I am sure that all these three types were built and inhabited at the same time by the same people. Moreover, the reasoning is cogent, as long ago suggested by others, that the existing pueblos are inhabited today by descendants of the cliff peoples, which have been no doubt somewhat modified in consanguinity by intermarriage with nomadic stocks, but have preserved the cliff-dweller cultus stage down to our own day in a partially but not greatly modified form. But while recognizing the kinship of the cliff dwellers with the modern Pueblo Indians, I can not restrict this relationship to any one modern pueblo to the exclusion of others. The evidences which are adduced that the cliff dwellers are ancestors of Zuñis can be paralleled by similar likenesses among the Mokis: indeed, the resemblances are even closer, since the Tusayan Indians are today less modified by foreign influences than any other pueblo peoples. The cultus stage of the so-called cliff dwellers is conserved to our times, with modifications, by the existing pueblos; and those members of the latter which are least modified stand nearest the ancestral conditions, and therefore nearest the cliff peoples.

Perhaps the most remarkable type of aboriginal dwellings in the Rio Verde Valley are the so-called cavate rooms which are found at various places where the rock is soft enough to permit their construction. These caves have been hewn out of the solid rock, and in places the cliffs are honeycombed with these habitations of aboriginal troglodytes. The largest cluster examined was about 8 miles south of Old Camp Verde, opposite Squaw Mountain, where their number is not far from a hundred. Each subterranean chamber or suite of rooms bore evidence of past habitation, and many objects of archæological interest were collected from their floors and the débris immediately at their entrances.

The accompanying illustration shows the external appearance of a row of cave dwellings south of Camp Verde; a huge buttress of soft stone of a character almost light enough to float, standing out from the lofty hills which flank the left bank of the river, and riddled on each side by caves, passages, and subterranean recesses. We clambered up the broken talus, shown in the view, and entered the caves through passages hardly high enough to admit a man of ordinary stature. Once inside the cave, the excavation enlarges, and we find ourselves in a roomy chamber, high enough to permit the visitor to stand upright, with lateral platforms, side rooms, closets, and recesses. These were living rooms, for there are fireplaces, well-plastered walls, and even the holes for former pegs for clothing. An enumeration of the number of rooms or cave habitations which exist at various points in the hills and mesas overlooking the Verde conveys little idea of the population

which once found shelter in them. There are evidences that the number was large, and warrant the conclusion that the caves were once alive with these troglodytes. The makers of these caverns chose for their work a soft tufa rock, which was easily excavated, rarely, if ever, attempting to excavate the hard lava or red sandstone. The aboriginal people riddled the hills in places with their burrowings. sometimes choosing caverns which they walled up, and when driven by exigencies, such as the hardness of the rock, plastered their communal dwellings like wasp nests to the face of the cliff which overhung them like great protecting roofs. The plan of the cavate rooms may be indicated by the selection of a typical form, shown in the accompanying cut. Some of these dwellings are simpler; others more complicated, but a marked feature of all are lateral platforms raised a few inches above the floor of a central chamber. It is instructive to note that this feature is paralleled in the construction of the floor of a modern kiva or sacred room, in which a raised dais or spectator's platform is a constant feature.

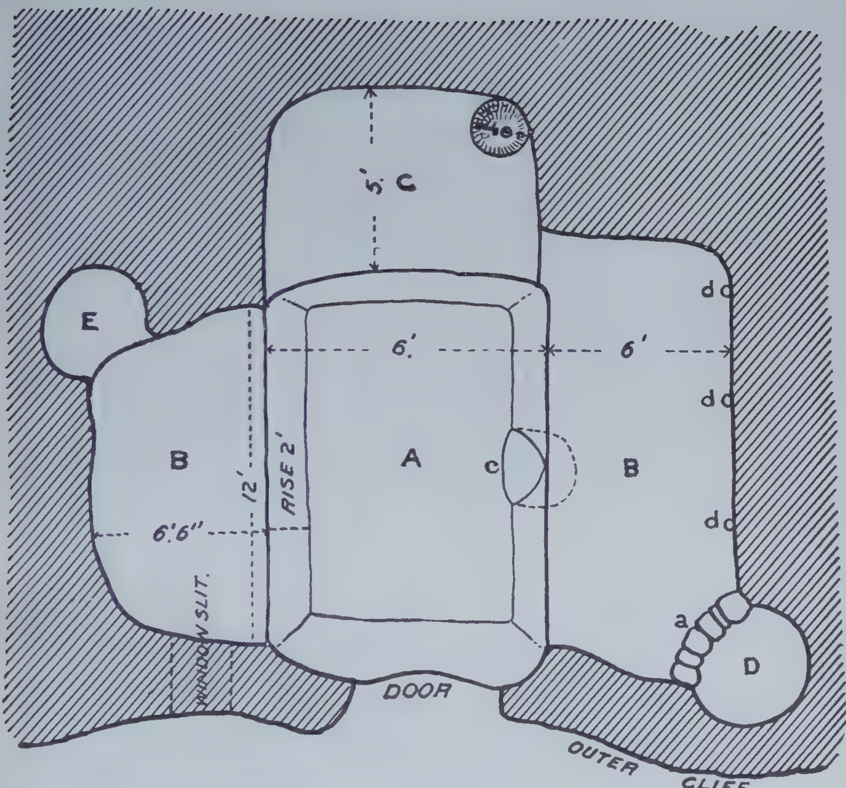
From the character of the archæological objects which were gathered from the rooms of these troglodytes, it is probable that they were of the same cultus stage as the cliff people of not distant mesas, or of extensive villages, the ruins of which now dot the Verde Valley or crown the hills at various points in this region. We do not have to go far for evidences that this is so, for even the promontories in which the cavate chambers are carved are surmounted with the remains of well-laid walls of dwellings, identical with those of the river valley.

The new ruins which I have discovered in the Red Rock country belong to the type called cliff houses, and are the largest of this kind already reported from the valley of the Rio Verde or its tributaries. So far as I know, these ruins have never been described, and one of the largest had never been visited by white men.

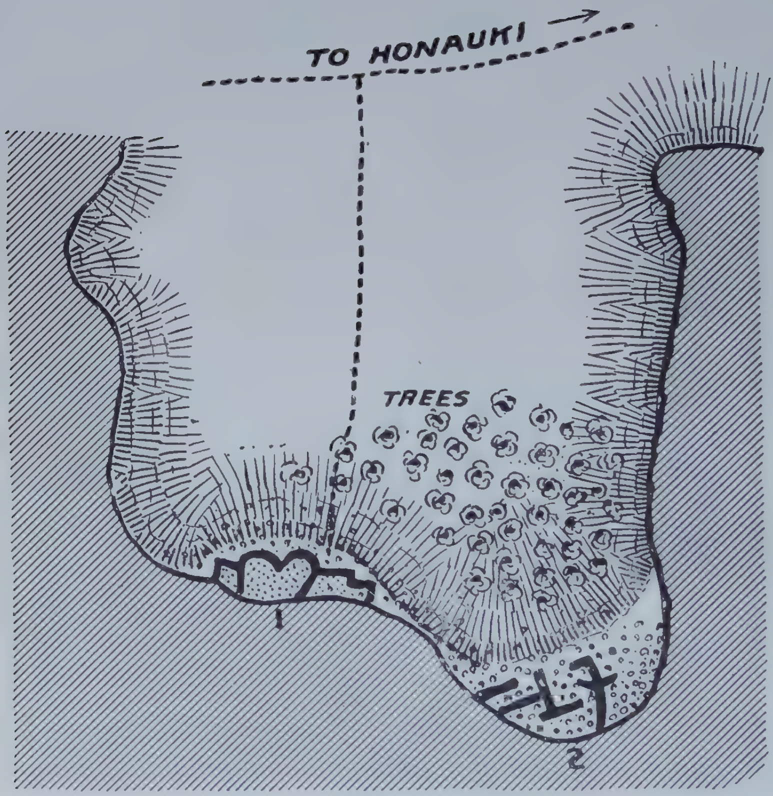
For convenience in my descriptions, I have given to the more important of these ruins the names Palatki and Honanki, Red House, and Bear House. The former would, at a low estimate, accommodate, when restored, 50 people; the latter, about 300.

Historical sources shed no light on their age, but I think there is hardly a doubt that they are older than the invasion of Arizona by the Spaniards early in the sixteenth century, while their general appearance speaks of a much greater antiquity.

The ruins of the Red Houses consist of two communal dwellings, situated a few hundred feet apart, about 6 miles west of Court House Rock, a prominent pinnacle overlooking the left bank of Oak Creek. These ruins lie in a box canyon on the south side of the Red Rocks, and are perched on the top of a talus of fallen débris from a perpendicular cliff to which they are plastered like chimney-swallow nests. The cliff rises precipitately behind the houses, and arching far above affords protection from falling rain which, so far as appearance goes, has never flooded their floors.



PLAN OF A CAVATE DWELLING.



PLAN OF PALATKI RUIN.

PALATKI (RUIN I).

There is no evidence that these ruins had been entered in recent years, and they were discovered by chance in side excursions while we were camped at Honanki, a few miles to the west. When we clambered into the deserted inclosures of the walls we saw basketry, stone implements, and fragments of cotton cloth lying in the alkaline dust, a sure indication that the collector had not preceded us. But aborigines had found shelter here before us, since the housebuilders disappeared, for the fragments of basketry are very similar to that made by Apaches, whose characteristic pictographs were represented on the walls. These were the vandals, no doubt, who, in their greed for firewood, had devastated the place, torn down the walls in places, and stripped the villages of many objects of ethnologic value.

The Red House ruins are approached by an easy trail through a grove of stunted trees which cover the fallen walls and the débris from the cliff. The first which was entered stands out in relief from the perpendicular face of the vertical cliff to which it is firmly cemented. The front walls consist of a number of curved sections, each corresponding with an inclosure, and giving greater capacity to the chambers between them and the cliff. This succession of bow-window like curves is not common in cliff houses, and seems to present a transition from between circular and rectangular houses. It is a cliff house in name, but it simply uses one side of the cliff as a wall to which the others are plastered. In the construction of the bulging facades, the builders utilized huge bowlders for parts of the foundation, so that the base of the wall follows the inequalities of the ground. The masonry is constructed of unhewn slabs of red sandstone, laid in adobe of the same color, and in places covered with plastering. When seen from the exterior, we detect evidences of three-storied rooms. The central portion of the ruin is almost intact, but on either wing time has dealt roughly with it, and there is little doubt that the nomadic tribes of Apaches, who replaced the sedentary agriculturists of the Verde Valley, have had a hand in the overthrowing of some of the fallen walls.

Clambering into the inclosure of the middle part of the ruin through an irregular opening at its base, we find ourselves in a roomy chamber inclosed by three walls 20 feet high. Halfway up the wall the holes, in which were placed the beams of the floor of a second story, can be easily seen, but the beams themselves have disappeared. This is but one of seven such inclosures each communicating with the next or opening externally by passageways a few feet square. The right-hand rooms have suffered much more than those in the middle or on the opposite wing.

The disappearance of wooden rafters and beams from this and neighboring ruins is accounted for by the fact that in the scarcity of firewood they were ripped out of the walls for use as fuel. Under the débris on the floor, hidden from sight, these logs are frequently found, showing that the roof had fallen in and covered them as it fell. It was noticed that the ends of these beams were literally gnawed off,

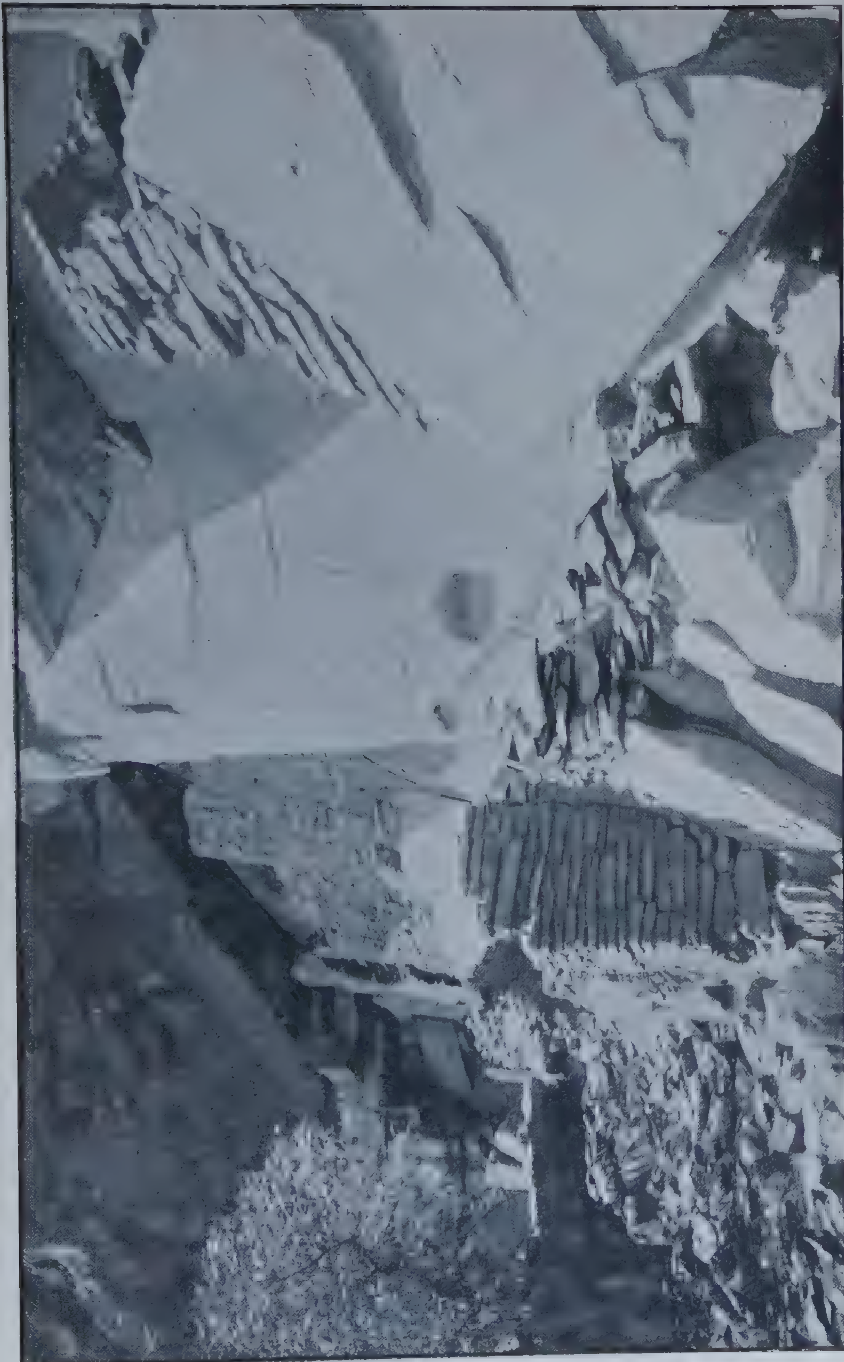
evidently by the use of some stone implement, a laborious process, as may well be imagined. A good illustration of this method of wood cutting can be seen in a log which I collected in one of the best preserved rooms of Bear House.

The second ruin of Palatki is built in a cavern of the same cliff, 70 feet across, and is totally covered by a projecting roof of overhanging rock. Its front wall is much broken, but enough remains to show that the rooms were in two series, one behind the other, and that at one time it was three stories high. There were six inclosures in each series, indicative of three stories in each, of eighteen rooms, the habitation of probably 30 persons. Such walls as were standing were of well-laid masonry smoothly plastered and were tolerably well preserved.

Excavations were attempted on a small scale in both the Red Houses, and numerous objects characteristic of cliff people were dug from the débris on the floor. Fragments of basketry, stone implements, woven fabrics of cotton cloth, and ropes of agave fiber were found in several rooms. Even fireplaces could be readily discovered, and in the ashes of that in a central room I found a fireboard identical with those now used to kindle fire in a New Fire ceremony at Walpi. In a niche near by there was a section of a large reed, closed at one end by an internode, and with a wad of cotton in the open end. It has been suggested, with great probability of truth, that this was a slow match for conserving a light after fire had been obtained by the fire drill. The specimens of cotton cloth were finely woven, in one case ornamented with an open mesh, an art in weaving still retained among Pueblo Indians.

Want of water and other practical difficulties made it impossible for me to carry on extensive excavations commensurate with the possibilities of discovery which these ruins present. There was unfortunately no available spring near these ruins, and we were obliged to bring drinking water from a long distance. The indications, however, are that this difficulty could be minimized, or if excavation of these promising ruins were undertaken at the proper season the supply of water and fodder for horses would be sufficient for all requirements.

Passing by several smaller cliff houses which I discovered in the Red Rock country, we may tarry for a few lines descriptive of the largest ruin of this region, to which I have given the name Honanki. The existing remains of this ruin show that it was a rambling row of two-storied houses extending for an eighth of a mile along the foot of a cliff, culminating in a large communal house, built in an extensive cavern with overhanging roof. Evidently this was a populous pueblo, large enough to accommodate at least 300 people, about the same population as Walpi today. Although there was good evidence that Honanki had been visited by other white men before us, we search in vain in archæological literature for even a mention of this prehistoric village. Fortunately enough of the structure remained to show the finished character of the masonry, and the large size of the former rooms. In



HONANKI (MAIN PART).

PLAN OF HONANKI.

(Main Part, A—(1)).

MAIN PART OF HONANKI.

(Outer wall of Room A.)

the main part of the ruin the walls still rise to a height of over 30 feet, and the wooden rafters still project from the masonry in several places at the level of the former floor. Thirty inclosures, some of which were four-storied, attest the former capacity of this forgotten village. In several of the rooms were ancient fireplaces filled with ashes of extinct fires, which long ago had blackened the walls with soot which was still visible. The well-worn stones on which the former people ground their corn were in place, and fragments of pottery were present everywhere in the débris which covered the floors. The fallen rubbish yielded a rich harvest of objects connected with the life of the former inhabitants, and in its alkaline dust, shielded from the rains by a common roof covering the whole settlement, we dug up many cotton fabrics, sandals of yucca fiber, objects used by prehistoric weavers, warriors, and farmers.

A problematical stone implement made of a small slaty stone mounted in a wooden handle, to which it was cemented by black pitch, was found a few feet below the surface on the floor of one of the rooms. This implement is unique, for so far as known it has not been duplicated from any cliff house near or remote. Opinions of experts as to its use are divided, but its double handle suggests an implement held in both hands when used.

Among most of the objects from these cliff ruins, however, there is a striking similarity to those reported by others from other cliff dwellings, which leads me to the conclusion that in studying them we have to deal with the productions of a people in a like stage of culture, extending from Utah on the north to the southern boundary of Arizona and beyond on the south, the limits of the so-called Pueblo peoples. As a rule, also, there is a remarkable similarity in the objects dug out of these ruins and those of the pueblos which have become extinct, which in turn are almost duplicated among the survivors in the inhabited pueblos. We are, in fact, dealing with the works of a people which, if not the same in blood, were practically the same in culture.

No aspect of southwestern archæology presents more interesting problems than aboriginal rock pictures, on which account especial attention was given by me, wherever I wandered, to the forms and import of figures cut or painted near the ruined towns on adjacent cliffs. Two radically different kinds of pictographs, ascribed to two distinct peoples, the house builders and the nomadic Apache-Mohave, are found on the rocks, yet but little experience is necessary to distinguish the two varieties. As a rule, the pictography of the cliff dwellers is pecked out, evidently with a stone, through a superficial layer of rock exposing a different colored, deeper layer. The Apache pictographs, however, are ordinarily painted or drawn on the surface of the rock and are not incised.

I have not here the opportunity to discuss the various figures characteristic of each kind of picture writing which was found, but will not omit reference to the pictured rocks of Cliff Ranch and those near the cavate rooms.

The majority of these pictures are totems of clans, but with them are many conventional symbols which have a widespread distribution in our Southwest. The most elaborate single figure of all, which covers a bowlder about 6 miles south of Camp Verde, is composed of a network of lines, recalling an irrigation system, a map of aboriginal ditches, remains of which may be traced for many rods over the surface of the plain at the base of the hill where it stood.

THE PROVINCE OF TUSAYAN.

ARCHÆOLOGY OF THE REGION.

Notwithstanding the country immediately around the inhabited Moki villages is one of the richest in ruins of any territory of like size in Arizona, up to the present no systematic attempt to carry on excavations in this region has been attempted. Yet archæologists are not wholly ignorant of the contents of these ruins, for collections of pottery, notably that made by the trader, Mr. T. V. Keam, have shown the general character, beauty of form, and rich decoration of ceramic ware found in them, and a memoir by Mr. Victor Mindeleff recounts some of the legends connected with these ruins and makes known the architectural character of the same. Unfortunately for the exact purposes of the archæologist, the special localities from which archæological objects previously gathered in Tusayan is doubtful or unknown, and their association too often problematical. If our conclusions are to be trustworthy we must have accurate data respecting the locality from which objects have been taken, and this may be made possible only by excavations at the ruins themselves.

With a view of arriving at this exactitude in data, I chose for my work in this country two well-known ruins, one of which is called Awatobi, the other Sikyatki. The names of both of these villages are known to Moki legends, and both are claimed as ancestral homes of the tribe. Guided by these legends, excavations in the ancient ruins I believed would be most fruitful, and it is not too much to say that the results formed the most valuable part of my summer's explorations in the Southwest.

THE RUIN OF AWATOBI.

The first reference in print in modern times to the ruin of Awatobi is found in the late Capt. J. G. Bourke's account of the Snake Dance of the Moquis, where he showed that the mounds called Tally Hogan by the Navahoes were ruins of Awatobi of Spanish conquerors. Later this ruin was described and figured by Mr. Victor Mindeleff in a report of the Bureau of Ethnology. Captain Bourke's reference to Awatobi, however, is very brief, and Mindeleff's ground plan defective, including only the ruin of the Mission of San Bernardino and adjacent houses, omitting the older or main part of the village—the western mounds. This omission I have already rectified, and in 1892 published the first complete ground plan of the ruin of Awatobi.

PICTOGRAPHS FROM VERDE VALLEY.

While the eastern part of the ruin, which is that figured by Mindeleff, undoubtedly supports his conclusion that this portion was "built about three sides of a rectangular court," had he recognized the original form, as shown by the western mounds, he would doubtless have modified his conclusions, for this part shows that the original Awatobi was a compact pueblo, destitute of an inclosed plaza or rectangular court, and that the eastern end, including the Mission of San Bernardino, is of comparatively recent construction.

When Tobar, the lieutenant of Coronado, with a handful of men, discovered the Tusayan towns, in 1540, the village of Awatobi was the first which he saw, and was one of the most populous. At that time, with the exception of Oraibi, it was the only Moki pueblo which was perched on a mesa top, all the others being in the plains or among the foothills. Tobar approached the town by stealth, during the night, and when discovered in the morning the intrepid Spaniard had his first encounter with a people who, unconquered by his successors save for a comparatively brief period, preserved their independence to the time Arizona passed under the control of the United States.

Awatobi joined with the other Moki towns in the great rebellion of 1680, when every Spaniard who was not killed was driven back into Old Mexico. In the early part of the seventeenth century, through the zeal of Padre Porras many Awatobeans had been converted to Christianity, and while other Moki towns hardened their hearts against the long-gowned men, as the priests were called, there lurked in the minds of the people of Awatobi a desire for the return of the priests. In 1692 Vargas came to the reconquest, and baptized many children at the spring near the ruin. What the hated Spaniards did not do, the other Mokis did. They combined together, and at the close of the year 1700 Awatobi was burned and razed to the ground. There can hardly be a doubt that this deed can be traced directly to the too cordial way in which, as they looked at it, Awatobi had received the dreaded Spaniards and the new religion which they taught. The tragic destruction of the place was a martyrdom of a town of 800 souls for its acceptance of Christianity, and had a similar tragedy, for a like cause, happened almost anywhere else save in the United States, or to any other race than Indians, its startling history would have been universally known.

The story of the destruction of Awatobi, thus forgotten by all save descendants of the actors, is the overthrow of a town of 800 people; a somber tragedy, where men were massacred in their sacred rooms after having been tortured with burning fagots and fumes of red peppers; captives, men and women, mutilated and slain, with all the barbarity known to a savage, because they looked with favor on Christianity. If the histories of our country were written from the Indians' point of view, this episode would long ago have attracted the attention of our historians. But historical documents are very meager in regard to the destruction of Awatobi. From scanty records we can

fix the date of the deed at 1700, but that is about all, and we know little of the event from these sources. Indian traditions concerning it have survived now for two centuries, and each succeeding generation of Mokis has told to its children the tale of Awatobi. From these stories we can learn something of the great tragedy which befell the town of the Bow people two centuries ago. Several variants of this legend of Awatobi are current at Walpi, but I have found that of Saliko, the oldest woman of the Snake family, one of the most comprehensive. She is particularly cognizant of the legends of events of those stirring times, as her maternal ancestor is claimed to have received from one of the women of Awatobi, who was saved, the badge of chieftaincy of a sacerdotal society, which she inherits. The story of Saliko runs as follows:

"The chiefs Wiki and Simo, and others, have told you their stories, and surely their ancestors were living here at Walpi when Awatobi was occupied. It was a large village, and many people lived there, and the village chief was called Tapolo, but he was not at peace with his people, and there was quarreling and trouble. Owing to this conflict only a little rain fell, but the land was fertile and fair harvests were still gathered. The Awatobi men were bad (*powako*, sorcerers). Sometimes they went in small bands among the fields of the other villagers and cudgeled any solitary workers they found. If they overtook any woman they ravished her, and they waylaid hunting parties, taking the game, after beating and sometimes killing the hunters. There was considerable trouble in Awatobi, and Tapolo sent to the Oraibi chief asking him to bring his people and kill the evil Awatobeans. The Oraibis came and fought with them, and many were killed on both sides, but the Oraibis were not strong enough to enter the village, and were compelled to withdraw. On his way back, the Oraibi chief stopped at Walpi and talked with the chiefs there. Said he, 'I can not tell why Tapolo wants the Oraibis to kill his folks, but we have tried and have not succeeded very well. Even if we did succeed, what benefit would come to us who live too far away to occupy the land? You Walpi people live close to them and have suffered most at their hands; it is for you to try.' While they were talking Tapolo had also come, and it was then decided that other chiefs of all the villages should convene at Walpi to consult. Couriers were sent out, and when all the chiefs had arrived Tapolo declared that his people had become sorcerers (Christians), and hence should all be destroyed.

"It was then arranged that in four days large bands from all the other villages should prepare themselves, and assemble at a spring not far from Awatobi. A long while before this, when the Spaniards lived there, they had built a wall on the side of the village that needed protection, and in this wall was a great, strong door. Tapolo proposed that the assailants should come before dawn, and he would be at this door ready to admit them, and under this compact he returned to his village.

During the fourth night after this, as agreed upon, the various bands assembled at the deep gulch spring, and every man carried, besides his weapons, a cedar-bark torch and a bundle of greasewood. Just before dawn they moved silently up to the mesa summit, and, going directly to the east side of the village, they entered the gate, which opened as they approached. In one of the courts was a large kiva, and in it were a number of men engaged in sorcerer's rites. The assailants at once made for the kiva, and plucking up the ladder, they stood around the hatchway, shooting arrows down among the entrapped occupants. In the numerous cooking pits fire had been maintained through the night for the preparation of food for a feast on the appointed morning, and from these they lighted their torches. Great numbers of these and the bundles of greasewood being set on fire were then cast down the hatchway, and firewood from stacks upon the house terraces were also thrown into the kiva. The red peppers for which Awatobi was famous were hanging in thick clusters along the fronts of the houses, and these they crushed in their hands and flung upon the blazing fire in the kiva to torment their burning occupants. After this, all who were capable of moving were compelled to travel or drag themselves until they came to the sand hills of Micoñinovi, and there the final disposition of the prisoners was made.

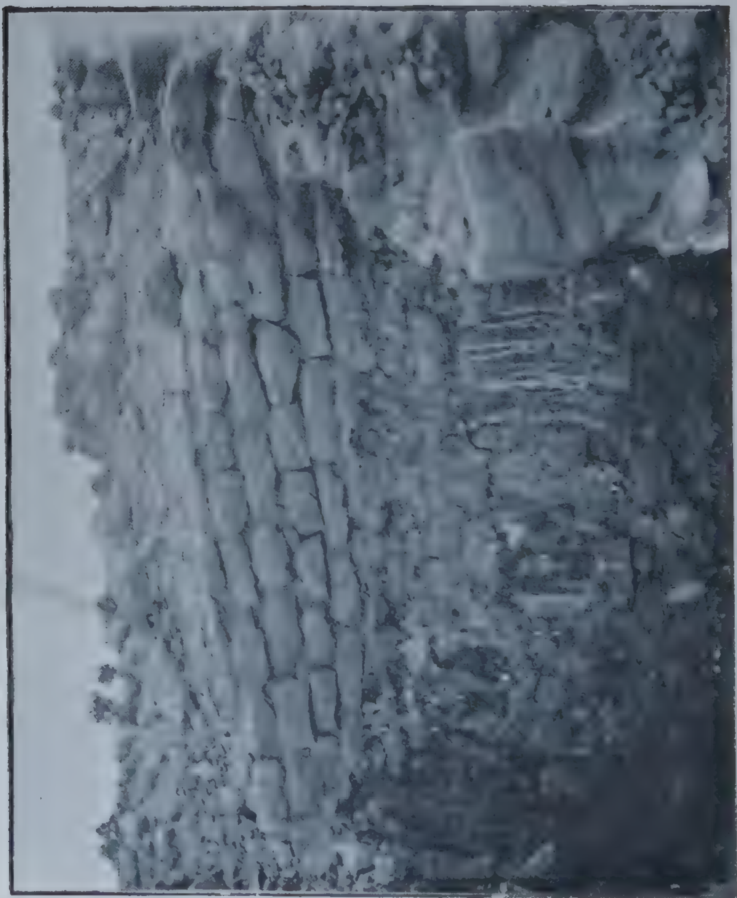
"My maternal ancestor had recognized a woman chief (Mamzrau moñwi), and saved her at the place of massacre called Maski, and now he asked her whether she would be willing to initiate the woman of Walpi in the rites of the Mamzrau. She complied, and thus the observance of the ceremonial called the Mamzrauti came to Walpi. I can not tell how it came to the other villages. This Mamzrau moñwi had no children and hence my maternal ancestor's sister became chief, and her badge of office or tiponi came to me. Some of the other Awatobi women knew how to bring rain, and such of them as were willing to teach their songs were spared and went to different villages. The Oraibi chief saved a man who knew how to cause the peach to grow, and that is why Oraibi has such an abundance of peaches now. The Micoñinovi chief saved a prisoner who knew how to make the sweet, small-ear corn grow, and this is why it is more abundant there than elsewhere. All the women who knew song prayers and were willing to teach them were spared, and no children were designedly killed, but were divided among the villages, most of them going to Micoñinovi. The remainder of the prisoners, men and women, were again tortured and dismembered and left to die on the sand hills, and there their bones are, and the place is called Mastcomo or Death Mound. This is the story of Awatobi told by my old people."

One of the most definite statements of this and all variants of the surviving legends of Awatobi is that many of the men were killed in a kiva. It is manifestly of interest to verify the tradition by excavations. In my limited work at the ruins in the summer of 1892, I

opened a chamber 28 by 14 feet in the middle of the rectangular court of the eastern portion of Awatobi, 100 feet north of the mission, and discovered a human skull and other bones which evidently had not been buried with care. This accorded with Hopi tradition pointing to this room as the kiva in which some of Awatobeans died on the fatal night of the massacre. I was at that time deterred from further excavations in the kiva by the horror of my workmen at desecrating the place. This summer, however, I determined to continue the excavations there and to follow the walls of adjacent rooms. The results led to a discovery which sheds new light on the character of the rooms in the middle of the rectangular court of the eastern part of Awatobi. Instead of a single room at this point, three square chambers of about the same size were found, side by side, and in the center of the floor of the middle room, 6 feet below the surface of the ground, I came upon a square stone shrine. As the workmen excavated to the level of the floor, I noticed in the middle of the room a large slab of stone through which had been cut a rectangular orifice. This slab was removed and below it was laid bare a crypt, the walls of which were made of four stone slabs, each set on edge, making a receptacle about 2½ feet square. This crypt was evidently a shrine or sacred receptacle in which prayer offerings were deposited in old pagan rites, for its floor was covered with remains of prayer sticks, some of which, colored with green pigment, were well preserved. It was without doubt a place of offerings to rain gods, for on each of the four stone walls which inclosed it a rain-cloud symbol was drawn in black pigment. The figure of the rain cloud thus outlined on the slab at the north side was colored yellow, that at the west green, that at the south red, and the slab at the east white, showing an association of colors with world quarters which still forms a prominent feature in Tusayan rituals.

The situation of this shrine in the middle of an ancient dance place is interesting in comparisons with modern usages, for even to the present day, in several of the inhabited Tusayan towns, the middle of the plaza, where ceremonial dances are performed, is occupied by a stone shrine in which prayer sticks are placed, as I have repeatedly described in my accounts of religious observances of these people. In modern conceptions this centrally placed shrine is said to be symbolic of a mythic opening out of which, in their cosmogony, races came in the beginning, from the Underworld, and there is little doubt that the same belief was associated with the buried cyst excavated at Awatobi.

The western or ancient portion of Awatobi is a high mound rising steeply from the south at the edge of the mesa and sloping gradually toward the north and west. It is probable, judging from the configurations, that when inhabited the buildings, the débris of which forms this mound, rose vertically from the edge of the cliff to a height of four stories and sloped by terraces to the level surface of the mesa on the north. By cutting into the mound on the steep side, we were able to



WALL OF EXCAVATED ROOM AT AWATOBI.

(Western mound.)

examine in vertical section the arrangement of rooms one above another. We excavated a number of almost parallel walls, apparently converging to the middle of the mound, and found the intervals between them to be cut off by cross walls into series of rooms. The deeper we penetrated the mound, following the level of the mesa surface, the higher the walls became; and if, as I suspect, these slightly converging walls penetrate to the heart of the mound, there is no doubt that the old part of Awatobi was a compact communal building four stories high. It is likewise evident from the shape of the mound that the western portion of Awatobi was of pyramidal shape, without inclosed court, although possibly penetrated by passageways or narrow streets. Drifting sand and falling walls have combined to form these compact mounds, from which no section of a wall rises above the general level; but wherever we penetrated below the surface there the walls remained unchanged, and if we dug down to the floor through the débris we found the remains of household utensils used by the former occupants.

The general features of rooms on the south or steep side of the western mound, as shown in the annexed plate, are similar. The masonry of the walls is composed of aligned stones, showing evidences of having been hewn or dressed with some care at construction. Plastering was generally present, and in many instances was as well preserved as the day the village was deserted. Rafters and floor joists had fallen and been buried in débris, but when dug out were found in such a good state of preservation that they were available for fuel. The builders who put them in place centuries ago had not known the saw or metallic ax, for each log had been laboriously cut with the stone implements with which he was familiar.

The appearance of an excavated room of the northern slope of the western mound may be seen in the accompanying plate. Here all indications point to the belief that we have a single-storied room, the rafters and other remains of the roof having been removed from the débris excavated from the floor. In one corner there was a small, square closet, and filling the interval between it and the opposite wall a raised seat. The walls were made of small stone blocks with nicely polished plaster, while the floor was paved and covered with adobe. The adjoining rooms over the whole northwestern area of the mounds showed little variation save in details.

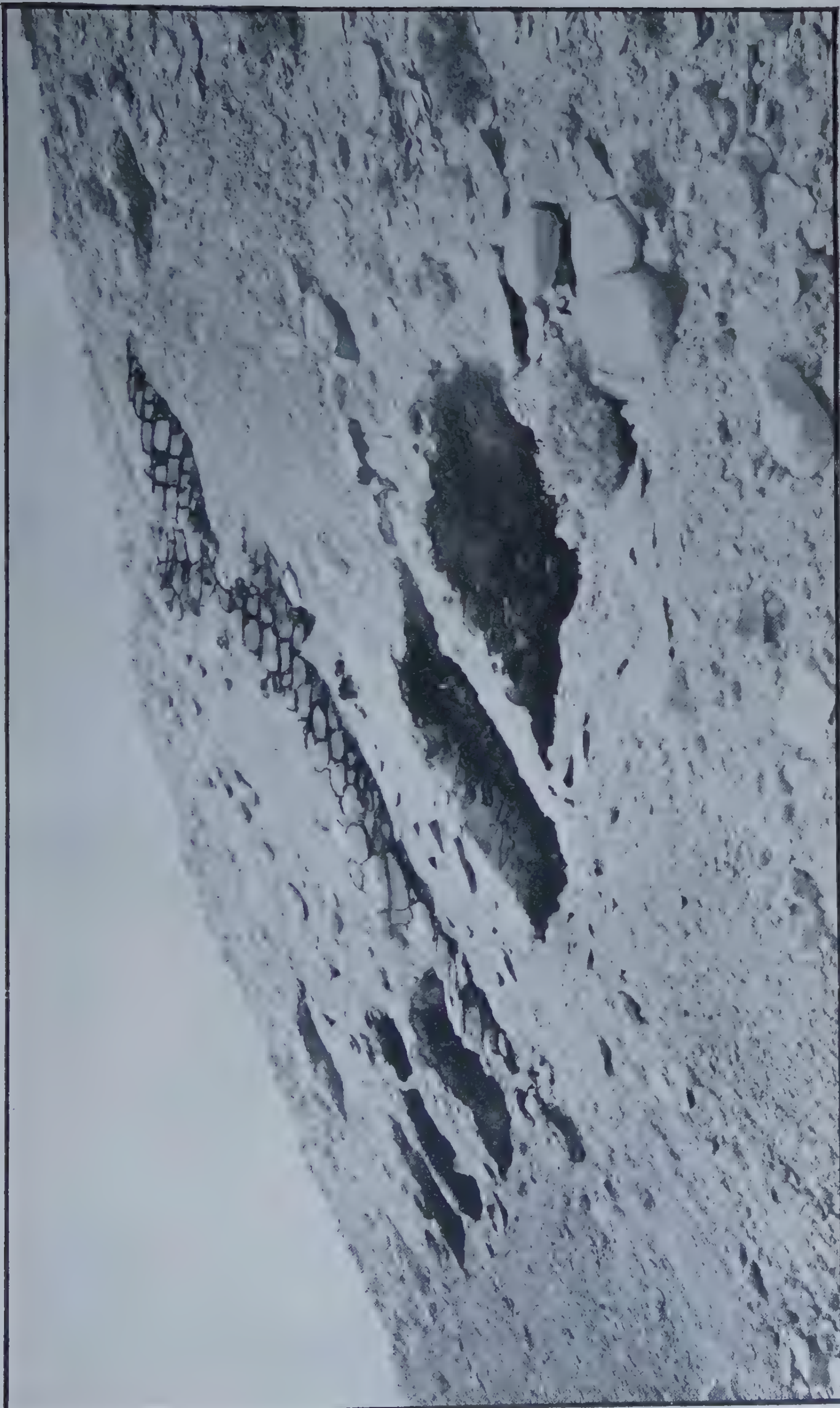
If, therefore, I may be permitted, in the light of my explorations, to reconstruct the original pueblo of Awatobi, as it appeared to the eager eyes of the Spaniards early in the sixteenth century, I should say that it consisted of a large communal building of pyramidal shape, four stories high at the apex, rising abruptly from the edge of a precipice on the south, and sloping gradually northward by a succession of terraces to a range of one-storied rooms. At that time there was probably a spur of rooms extending eastward and facing a dance plaza, in the middle of which was a kiva and shrine. At the close of the

next century there had been added the eastern part of the pueblo, the Mission of San Bernardino, erected at the edge of the cliff and connected with the spur on the north side by a lofty wall in which was a wide gateway, remnants of the buttresses of which can still be traced. Through this gate the hostiles poured on that fatal night, almost two centuries ago, admitted to the doomed village by a treacherous chief, and in the southeast corner of the court, in front of the church, transpired one of the most brutal tragedies of the times. That many persons were massacred a few feet from the church is shown by the many skeletons which have been found there, evidently thrown promiscuously in a heap, without pious regard or the sympathetic offering of food in mortuary vessels.

It was evident from my excavations that the fury of the assailants was especially directed against the eastern quarter where the mission was situated, which is easily explained on the ground that the dwellings of the party favorable to Christianity would naturally be in that section. The evidences of a great conflagration, which appeared everywhere in this part, showed in several houses where granaries of corn had formerly been. A hostile band would not have thus destroyed food material unless its rage had been great or the conflagration beyond its control. It was not apparently the purpose of the hostiles to sack Awatobi, but to effectually root out its sorcery—the dreaded innovations in pagan belief which the zeal of the padres was making in its midst.

For prehistoric customs of the aboriginal life, unmodified by the Spaniards, we must look to the western section. The excavations in different regions of this part brought to light a strange mortuary practice. It has long been known that the prehistoric villagers of our Southwest buried persons of distinction in or on the floors of their dwelling rooms. Instances of intramural burials have been reported from the Gila and Salado Valley ruins and the ancient ruins of Cibola called Halona (Zuñi) and Heshotau'hla, but up to the present no case of Tusayan house burial has been found. My studies of Awatobi, however, show the existence of this custom in that town.

One of the best of these house burials was found in a chamber on the south side of the western mounds, near the edge of the cliff. On opening a room at that point we found unmistakable evidences that it was a burial chamber, for resting on the floor a skeleton was discovered stretched at full length, the head slightly turned to the northeast. Around this skeleton had been placed as mortuary offerings or symbols of rank, a collection of objects of such a nature as to indicate that it was that of a chief, and Kopeli, a competent authority, declared that the evidence showed this to be the remains of a warrior priest. Eight pieces of pottery lay near the bones of the head and breast of the dead chieftain. Four of these vessels were small, globular paint bowls, made of black and white ware, and placed inside a beautiful vase of red color. These small receptacles contained the warrior's paint, red



EXCAVATED ROOMS OF WESTERN MOUND OF AWATOBI.

EXCAVATED ROOM OF AWATOBI.
(Northwest mounds.)

and yellow pigments, and a micaceous hematite, which is still used by the Snake priests and other warriors to decorate their cheeks on ceremonial occasions.

A beautifully decorated black and white ware vase stood near by, covered with an inverted ladle, and containing several arrowpoints of finest workmanship. There were no food vessels or basins as in ordinary burials, and no original means of entrance into the chamber of death could be found. The chief had been entombed in the room with pious care, and afterward the walls of masonry were sealed about him. There were no evidences of post-mortem entrance to the chamber, and nothing to show that it was a living room subsequently to the burial. The mode of intramural interment was not common at Awatobi, but most of the dead were buried outside the town, as the cemeteries north and west of the village abundantly prove. It is significant that this solitary instance of house burial was found in the oldest part of the ruin, and it is probable that after the advent of the Spaniards the custom was abandoned, except in those instances where the walls or floor of the mission were used for that purpose.

The Awatobeans buried most of their dead outside their village in the shifting sand dunes north and west of their old town, and in the foothills at the base of their mesa. The interments in the sand were generally, as in modern Tusayan burials, found to be accompanied with food bowls of finest yellow ware, or with rude cooking pots or bowls and slipper-shape jars, in all of which fragments of food were detected. Most of the skeletons from these cemeteries which were examined had been placed in a sitting posture, the knees brought up to the chin, and the pottery offerings were deposited at one side. Several of the dead had wooden slats painted green, which, in one instance, was held in the left hand. This offering, called a prayer stick, was decorated with two figures of the dragon fly painted in black outlines.

The interments at the base of the mesa seem to have been made in shallow graves among the rocks, and were accompanied with food offerings deposited in decorated bowls. In one of these graves I found two nests of food bowls, each composed of six specimens, one at the side of the other. At another grave, which was identified as that of a person high in sacerdotal standing, there was a colander pierced with a double row of holes arranged in the form of a Greek cross, and filled with stone arrowpoints, charm stones, and pigments. This colander may have been used by the priest in sifting sand on the floor of the kiva or sacred room when he made the sand picture, an important accessory of the altar. At the skull of the same priest there was a stone fetish of the puma, and near his breastbone an elaborately carved prayer stick, upon which the impression of a feather was still to be seen. How long ago these objects were placed by the survivors on the graves of their kindred I can not say, suffice is it to know that funeral habits still practiced by the Mokis find their counterpart in villages of their

kin which were destroyed centuries ago. The ethnologist who reads aright the evidences can no longer ascribe the custom of placing food upon the grave as one derived from the Spaniards. It is aboriginal, and, as we shall later see, was customary in Tusayan before a single christian had trodden the soil of Tusayan.

From the rich collection of objects which were brought to light by my excavations at Awatobi, I will mention only a few of the more interesting. The town was directly under Spanish influence sporadically from 1540 to 1700, and it is not astonishing to find traces of this influence. During that time was built the Mission of San Bernardino, a large building differing in architecture from the aboriginal houses. In excavations near the ruins of this mission, I found metallic objects, a rusty knife blade, copper fragments, nails, glass, and glazed pottery. These and similar objects seem to have been introduced in considerable quantity, considering the isolation of the province and its difficulty of access. We may well suppose that the influence of the Catholic priests on manners and customs was even greater than that indicated by the foreign objects which were brought with them. At heart, no doubt Awatobi was still pagan when the other pueblos destroyed it, and the majority of the objects found are therefore strictly aboriginal in character.

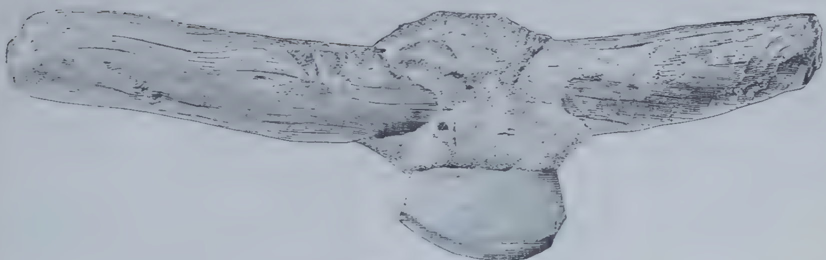
The pottery which was collected at Awatobi belongs for the most part to the fine yellow ware for which Tusayan is famous, with here and there bowls made of black and white ware, the distinctive pottery of the cliff builders. It consists of coarse coiled ware, cooking vessels, and shoe-form vases, with ladles, jars, and amphoras, numbering in all about a hundred pieces. To articles made of clay baked in the sun and fired by the heat of coal are referred bird-like pendants, some of which are in the form of snell gorgets, painted and incised. The Awatobi priest used a cigar-holder form of pipe, in which native tobacco was smoked during ceremonials.

A single small clay bell, similar in form to copper bells from Old Mexico, is unique, having never before been duplicated in Tusayan ruins.

We know from historical sources that the Awatobi priests at the time of the Conquest wore cotton kilts, and in early documents it is stated that they presented many "cotton towels" to Antonio de Espejo when he made his way to Tusayan in 1583. Although woven ropes were found in one of the older houses, no cotton fabrics rewarded our search. The ropes and strings which were found were made of the tough fiber of the agave. The bones of the turkey and other birds were worked into awls, bodkins, needles, and pins. Cut into sections, the leg bones of birds were used as necklaces, and one of the longer of these sections was pronounced by the Indians a whistle, such as is now employed in the secret rites of the inhabited pueblos.

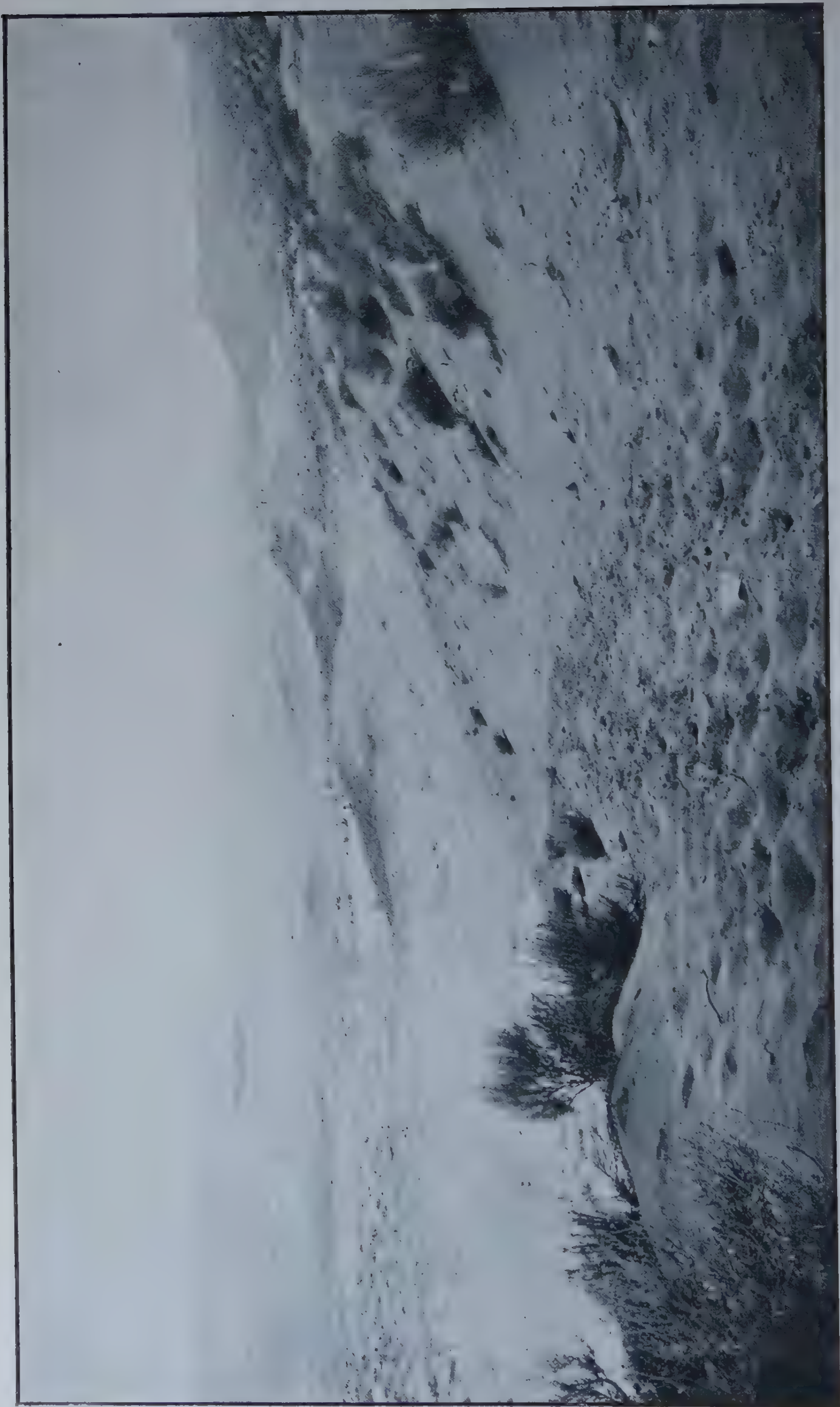
The turquoise was prized then, as now, as an ornamental stone, and

CLAY BELL FROM AWATOBI.
(Natural size.)



STONE IMPLEMENT (PALATKI).
(One-third natural size.)

TINDER TUBE (PALATKI).
(Natural size.)



SIKYATKI MOUNDS FROM KANELBA TRAIL.

the nicely perforated and skillfully cut beads of this material made by the ancient people of Awatobi are similar to those used today. These turquoises, however, traveled many miles before they fell into the hands of the Awatobi people.

With the exception of the pottery it was in stone implements that our collections were richest of all. Axes, arrowheads, spearpoints, and grinding and polishing stones occurred in great numbers, and several nicely fashioned grooved stones used to straighten arrowshafts, stone slabs for paint grinding, metates, and pestles of similar shape and manufacture to those universally found in the ruins of the Southwest were added to our collection.

The ancient Awatobi priests, as do their descendants to-day, prized any botryoidal stone, quartz crystal, stalactite, fossil cephalopod, or bright-colored rock. So closely similar is the life at Walpi to-day to that which existed in Awatobi at the close of the seventeenth century that the intelligent workmen whom I employed from the former village were able to name and tell me the use of almost every object found, thus verifying my interpretations. Where customs change so little in so many generations, archæology is simply an ancient aspect of ethnology.

THE RUIN OF SIKYATKI.

Three miles east of the pueblo of Walpi, among the foothills which skirt the mesa on the south side, lies a collection of mounds which were said to be the site of an old pueblo called Sikyatki, or Yellow House.

My knowledge of this ruin dates back to 1892, when, in strolling over the hills, it was pointed out to me by an Indian, and the romantic history of its destruction by the Walpians told by my companion. Although this pueblo, judging from the size of the mounds, must have been one of the most populous in Tusayan, comparatively nothing is known of the character of the people who inhabited it.

The destruction of Sikyatki occurred, according to tradition, before the coming of the Spaniards, and therefore in prehistoric times. To the definite statements to that effect made by old priests at Walpi, corroboratory evidence of their truth is found in the fact that the place is nowhere mentioned in ancient documents relating to the history of the country. No doubt is entertained by anyone that Sikyatki is a prehistoric Indian pueblo, but there are no data at hand to determine its age.

The probable antiquity of this ruin imparts to the rich collection of archæological objects collected from it a special value, revealing the character of Tusayan life in prehistoric time. According to traditionists, the village of Sikyatki was settled by a phratry of Mokis called the Kokop or Fuel people, which are still strong in numbers at Walpi. It took its name, they say, from the color of the water of the neighboring spring, which still preserves its yellowish appearance. The cause of its destruction was a culmination of bickerings and altercations between

its inhabitants and those of Walpi, which was then situated on foothills to the west of the mesa, not having yet been moved to its commanding position on the summit. The outcome of many disputes between the two pueblos brought on a tragic destruction of the place, after which such of the hostile element as escaped fled to Awatobi, then a flourishing village, 15 miles away; the remainder were incorporated with the population of the victorious town. A sanguinary story of adventure is woven into the legends relating to the causes of this destruction of a whole village. One of the youths of Sikyatki, disguised as a dancer and wearing a mask, killed a woman spectator while a ceremony was in progress at Walpi. He escaped from the town, ran along the cliffs, taking off his mask and boasting of his deed. These taunts inflamed the Walpians to vengeance, and when the men of Sikyatki were occupied in the fields their warriors fell upon the town and destroyed it. There is no way to prove the truth of this legend, but there can be little doubt that Sikyatki fell many years ago. It is interesting to remember that in those old days Walpi was probably the only other Tusayan town at the East mesa, and therefore the only rival which Sikyatki had near by. The Tanoan people, whose descendants now inhabit Hano, the nearest village, had not migrated from the Rio Grande, and the little town Siteomovi, midway between Hano and Walpi, had not been built on the mound covered with flowers which gave it its name.

As one crosses the plain following the road from the entrance to Keams Canyon to the modern Moki settlement near Isba or Coyote Spring, the main water supply of Hano, he sees far to the right, on the mesa top, two conical mounds, which are conspicuous for miles. These teocalli-like elevations are called Küküteomo, and are circular ruins, possibly contemporaneous with Sikyatki, of which they were defensive outlooks. They are situated just above the mounds which mark the ruins of that village on the foothills beneath, and were no doubt wisely chosen for defense against the Walpians. Between them and the present towns the mesa narrows, and what was once a strong defensive wall can still be traced, crossing the mesa at its narrow point. Sikyatki lies among foothills, surrounded by stretches of sand, elevated a few hundred feet above the plain. Elsewhere than in Tusayan its site would be regarded most desolate, but an enterprising Indian, claiming the ruin from the relationship of his wife, still harvests from these barren sands a considerable crop of melons and squashes, planting his vines where the plaza once was. Other Indians claim the stunted peach trees which grow near by. Not a trace of the walls of ancient Sikyatki stand above the mounds, although the outlines of houses can be followed everywhere on the surface. Since the village became a ruin roofs have fallen in, drifting sand has blown into the chambers, and the sagebrush and other desert plants have taken root in the covering débris, forming a succession of mounds of rectangular

GROUND PLAN OF SIKYATKI.

arrangement, whose only habitants are reptiles and noxious insects. Such is the desolation of an ancient pueblo where once lived a people who manufactured in prehistoric times some of the most artistic pottery ever made in North America. Even the Indians from the neighboring villages who visited me and saw the beautiful ware which I exhumed from these desolate mounds and sands did not fail to contrast the past with the present. The best potter of the East mesa, an intelligent woman from Hano, named Nampio, acknowledged that her productions were far inferior to those of the women of Sikyatki, and she begged permission to copy some of the decorations for future inspiration. The sight of this dusky woman and her husband copying the designs of ancient ware and acknowledging their superiority was instructive in many ways.

The northeast corner of the rectangular mounds of Sikyatki rises into a rocky pinnacle, steep on the north and sloping by a gentle rise from the south and east. This elevation was formerly crowned with houses, as will soon be made evident, and from its commanding position was early in our work called an acropolis. The accompanying plan of the whole village shows that it was rectangular, with northern and western ranges of houses much higher than the southern and eastern. This is readily referred to the contour of the foothills chosen by the ancient builders as the site of their town, the high rock of the acropolis being, without doubt, the first part on which houses were erected. The four elongated sides which give the rectangular form to the mounds inclosed a rectangular court in which are smaller mounds, remnants possibly of kivas, and level spaces now marked off with rows of stones inclosing modern fields of melons and squash plants. At the southern angle two significant buttresses in the bounding mound suggest a gateway by which the court of the village was entered. Some archaeologists have insisted that the rectangular form of pueblos is a modern type, but the ruins of Sikyatki take this form back to prehistoric times.

In considering a ruin as large as Sikyatki, it is quite impossible for me in the limited space allowed in this preliminary report to do more than choose a few typical rooms in order to give an idea of the character of the architecture of the habitations of the Sikyatkians. I have, therefore, chosen as a type the rooms of the acropolis, which were carefully excavated under my direction by Kopeli, the Snake chief, one of the best Indian workmen employed.

When I began excavation at this part of the ruin, we had no trace of walls to guide us, but by removing the surface débris we found a double line of rooms forming a ridge extending about north and south, following the rise to the top of the rock, which was about level at this point. The rooms were excavated to their floors, where a stone pavement resting on the rock was found 5 feet below the surface. The walls were constructed of squared stones, set in adobe mortar and smoothly plastered with the same material.

The accompanying cut shows the ground plan of nine of these rooms, which for purposes of study are lettered *A* to *I*, accompanied with dimensions. It will be seen that the largest were about 8 feet square, of regular shape, and that the smallest was a narrow recess not communicating with the others. Several of the chambers had passageways connecting them as indicated, and no doubt belonged to the same household.

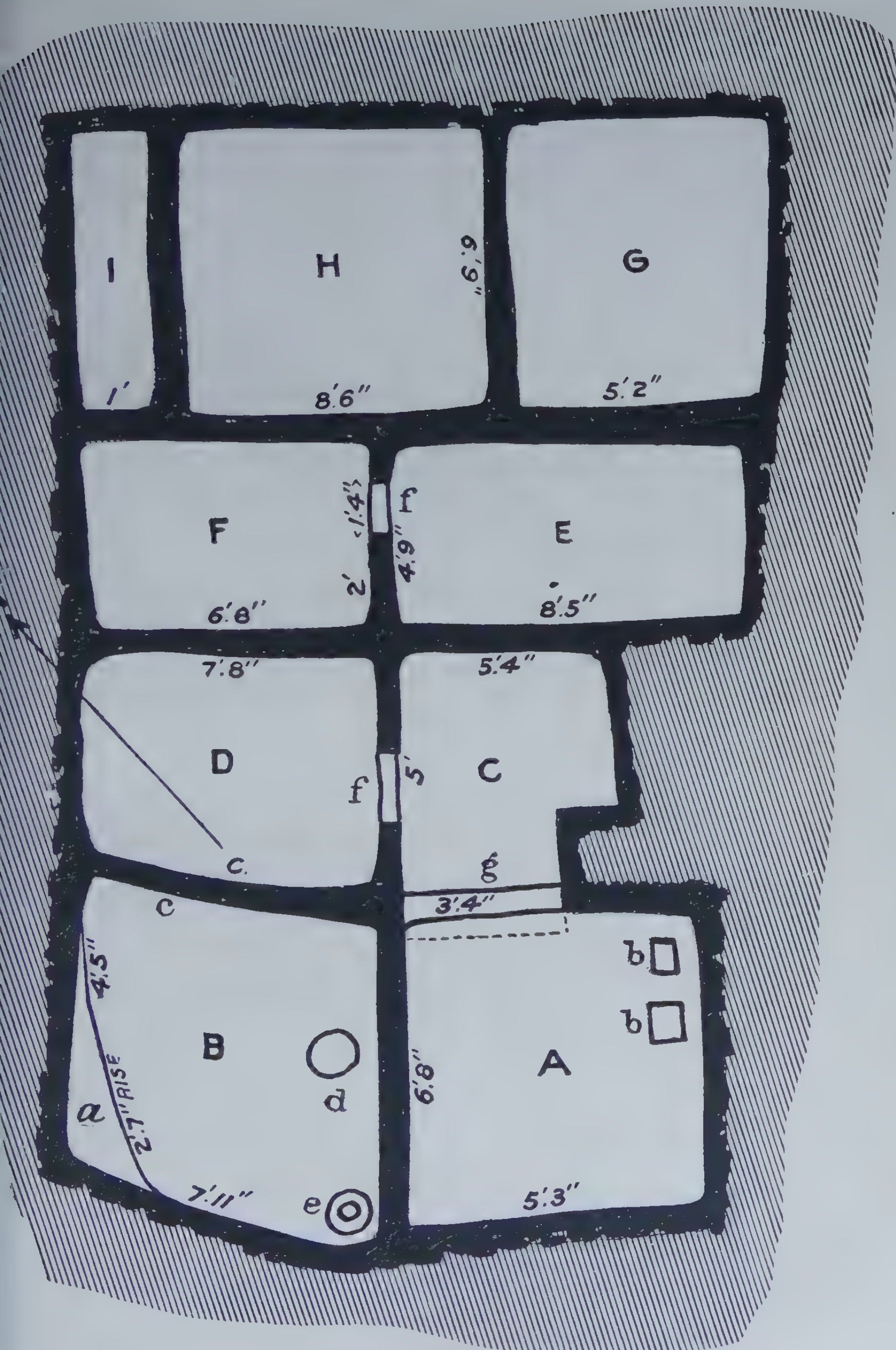
On the sides of the walls I found several niches or cubbyholes nicely plastered, in which objects used in daily life had been left over three hundred years ago when the rooms were abandoned, and the soot of ancient fireplaces still intact had not been obliterated during the generations during which the walls had been buried. In one corner of room *A* we found a large, coarse jar, in which no doubt water for daily use had been kept or possibly the food cooked, and numerous other jars littered the floor. The plastering of the masonry in rooms *G* and *H* was especially well done, and a portion of it when removed and cut in section exhibited many strata, showing the many times some careful housewife had replastered her house, or transmitted this task to descendants.

The majority of the objects found at Sikyatki were obtained from extramural cemeteries which are situated in sandy places, on three sides of the town, a few hundred feet beyond the outer walls. A choice collection of food basins of remarkable fineness and beauty of form and decoration were obtained from these burial places. These and the many smaller objects found with them present a most instructive picture of prehistoric mortuary customs.

It was customary for the Sikyatki, as for the Walpi Indians, to place pottery, with food and prayer sticks, fetiches, and stone implements in the graves of their dead. As these objects from the graves bear unmistakable evidence of having been in use previously to burial, we can obtain from an examination of them a good idea of household utensils used by the Sikyatkians. Moreover, the dead were at times buried with their personal ornaments and ceremonial paraphernalia—insignia of rank, and the like—all of which, when rightly interpreted, are most important in the study of the life of prehistoric Tusayan.

The number of skeletons which were found reached into the hundreds, and as almost every burial was accompanied by one or more food vessels, vases, or ladles, the number of objects obtained was correspondingly large. The majority of the skeletons, on account of their great age, were in a very poor state of preservation, and in most cases only a fine dust indicated the presence of the dead.

From my knowledge of surviving customs at Walpi, it was possible in some instances to determine the sex and standing in the tribe of the dead from votive offerings, a work in which I was aided by intelligent priests who visited me during the excavations. No trace of metal or other material which showed the influence of white man was discovered



PLAN OF EXCAVATIONS ON ACROPOLIS, AT SIKYATKI.
(Dimensions in feet and inches.)

EXCAVATED ROOMS AT ACROPOLIS OF SIKYATKI. LOOKING EAST.

at Sikyatki, and the conclusion is logical that in studying the objects from this ruin we are considering the unmodified, purely aboriginal cultus of Tusayan.

The bowls and other kinds of pottery found in the Sikyatki cemeteries in most instances contained the remains of votive food offerings, the character of which obviously could not be made out. In addition to perishable foods, other objects, like stones, arrowheads, beads, and prayer sticks, were likewise placed in the earthenware pottery by the side of the dead. One of the most interesting of these mortuary offerings was a small, textile fabric—the only one of this kind which occurred—resembling a feather cloth. As the production of feather garments, blankets, cloth, and the like was extensively practiced by the cliff dwellers, and its fabrication is recounted in many Tusayan legends, it is instructive to find evidence of it in this old Tusayan ruin.

By far the most novel of wooden mortuary objects found in Sikyatki graves were the so-called prayer sticks, of which a number of different kinds were exhumed. These prayer sticks varied in form from simple wooden slats to pencil-like rods carved with ferules. Considering, as we must, that they were cut out with stone implements by people ignorant of metal knives, they are fine examples of Stone Age wood carving, even although the wood of which they were fashioned is soft and easily worked. As a rule, they were painted with pigments of two colors, green and black. The green is a powdered carbonate of copper, fragments of which were likewise found in the graves. Certain of the prayer sticks were identical with those now used by the Flute fraternity at Walpi, thus supporting the claim made by this society that their ancestors were among the most ancient people in Tusayan, and were early represented at Sikyatki. The presence of a prayer offering similar to that characteristic of the Flute priesthood would seem to indicate that the person in whose grave it was found belonged to that family. One of the largest of these prayer sticks was that shown in the accompanying illustration, which is a remarkable form, not used at the present day. So well preserved are some of these wooden prayer offerings that the imprint of feathers and pine needles can still be detected upon them. Many of these prayer sticks are undoubtedly offerings to Masauwûh, the Death God, and it is interesting in this connection to mention the fact that at the close of work each day the Indian laborers prepared a twig with attached feathers, which they placed in the trenches, sprinkling them with sacred meal, and at the same time breathing a prayer to the dreaded Death God, whose realm they had invaded in disturbing the graves. The horror at disturbing the dead, and the superstitious fear which led the Mokis to refuse to touch a human bone, was thus, to them, satisfactorily offset by propitiatory observances.

Several pipes, one of which was of especially fine workmanship, were found in the graves. These pipes were shaped like cigar holders, short

and stemless, the surface, in a few instances, decorated with incised lines. Their presence in graves is readily explained when we remember that originally smoking was a ceremonial habit, and a certain reverence is still paid by the priest to the pipe, which he uses in the celebration of the mysteries. The fragments of one herb found in one of the food basins has been identified as probably belonging to the genus Nicotiana, the native American tobacco plant, and it is well known that even to the present day food offerings, sprinkled with dried tobacco leaves, are made before certain feasts following great ceremonials. A well-made stone fetish of a mountain lion, found with a bowl of arrowheads, was thought to indicate that the dead with which they occurred belonged to a warrior society. The lips of this fetish still showed the red pigment with which they had been painted.

Fragments of obsidian were apparently highly prized by the ancient people of Sikyatki. From this material, which had been carried a long distance to reach Tusayan, arrowheads were made. As a substance of value it was deposited in masses in the mortuary vessels.

There is evidence that the ancient people of Tusayan used coal for fuel, seams of which underlie their pueblos, but in course of time this substance had fallen into disuse, so that it is unknown as a fuel today.[1] Coal in the form of lignite was also polished into ornaments, a slab of which, perforated for suspension, was taken from one of the graves. Similar polished lignite slabs also occur in graves and elsewhere in ruins as far south as the Gila, and from the province of Cibola or Zuñi.

The well-known turquoise beads were prized for ornamental purposes by the ancient Sikyatkians, and their existence in prehistoric graves implies barter with distant people of the Rio Grande. Slabs of mica and selenite were drilled and fashioned into pendants to be worn on the neck or in the ears. The most common form of necklace was made of short segments of the leg bones of some birds strung together. These were stained green; and from around the neck bones of one skeleton which was exhumed a many-stranded necklace of this kind was taken, some of the beads of which still preserved the green color. A saucer-like basin contained several scores of hard seeds, each perforated and apparently used for beads.

A large number of mortuary food basins contained small, smooth stones similar to those still used in polishing pottery. With these were likewise concretionary nodules, quartz crystals, fragments of stalactites, and in one instance a fossil cephalopod. A similar shell is one of the most sacred objects contained in the badge of chieftaincy of a woman's society called the Lalakoñtû at the present day, and we may rightly suspect that it was held in like reverence in old Sikyatki.

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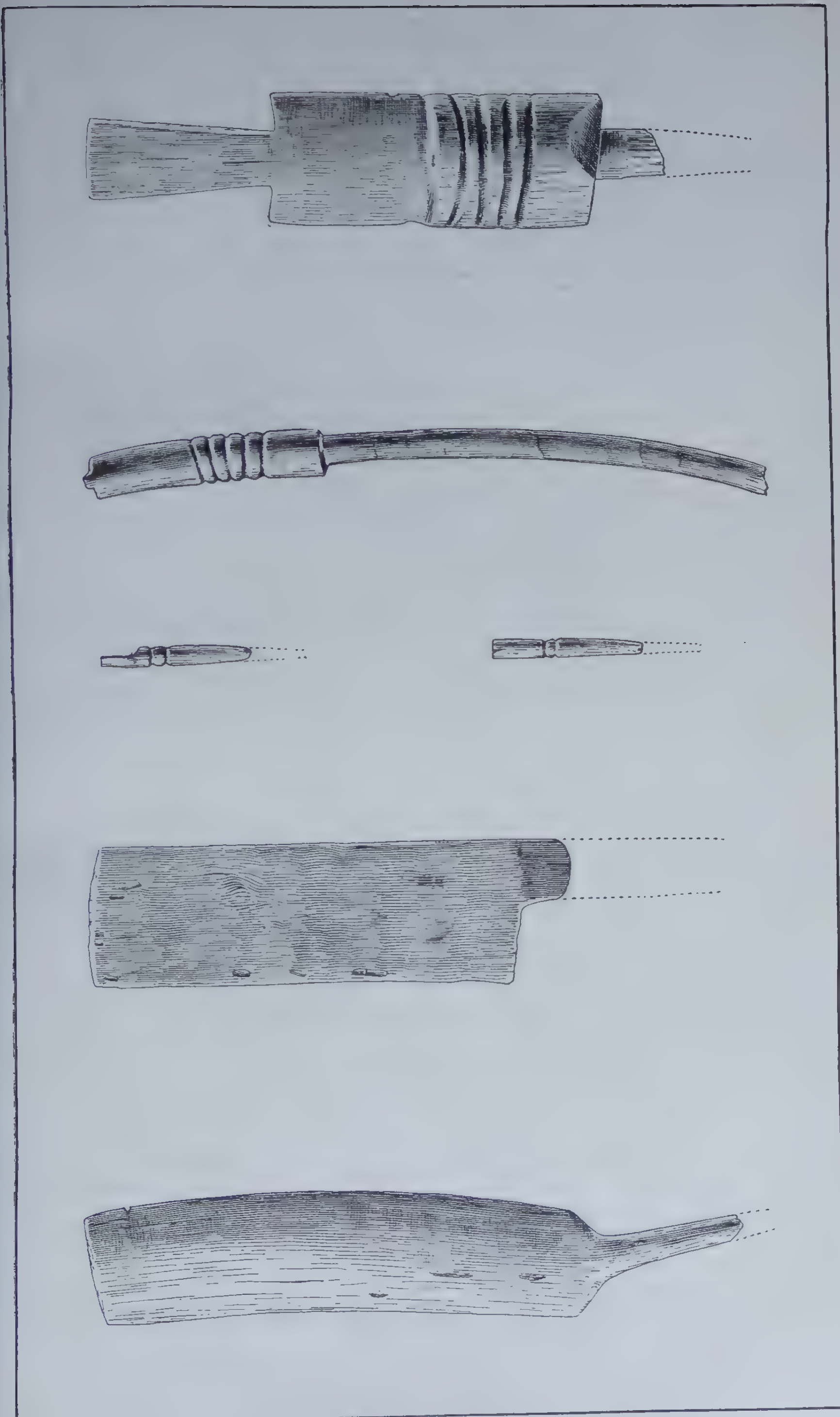
[1] This change probably took place at the introduction of sheep, whose dried droppings are now used in firing pottery.



MORTUARY PRAYER STICKS (SIKYATKI).
(Nos. 156181 *et alii.*)

MORTUARY PRAYER STICK (SIKYATKI).
(Natural size. No. 156179.)

KAOLIN DISK (SIKYATKI).
(Natural size. No. 156164.)

Repeated questioning of the Snake chief, who was one of my workmen, failed to elicit any legend that the Snake family once lived at Sikyatki, but a rattle of the rattlesnake found in a mortuary food vessel calls to mind the reverence with which this reptile is held by the two societies of priests which biennially celebrate the well-known snake dance.

The small red disks punctured near the rim are regarded as ear ornaments. Some of these are notched on the border, as if to facilitate winding with string, while others were unperforate, slightly convex on each side. Some of these pendants were rectangular, but generally smooth and highly polished. Two specimens of the shell, *Oliva angulata* Lam., were found in one food basin, which indicates either that the Sikyatkians traded with those tribes who obtained it from the Gulf of California or that it passed by barter among peoples who did. Their occurrence likewise shows that in prehistoric times seashells were prized by the Sikyatkians in much the same way as at present.

Most problematical of all mortuary objects are the large white disk-shape fragments of kaolin, which are artificially fashioned and perforated at the axis. One of these was found upon the cranium of a skull, over which it fitted like a crown.

The cylindrical clay object, with reticulated surface, was immediately identified by Indian workmen as an imitation of a corn fetish, whose surface was formerly studded with seeds of maize. A similar ceremonial object is displayed at the present day on the altar of a woman's society called the Lalakoñtû, and in elaborate purification ceremonies called Powamû. The presence of these ceremonial objects in prehistoric graves, in form almost identical with those at present used in secret ceremonials, shows the great antiquity of portions of the Tusayan ritual and opens a vista into prehistoric rites of these Indians.

Many graves had votive dippers, ladles, or small square clay boxes, with or without handles, resembling medicine bowls, holding fragments of green or red stones or finely ground pigment of the same colors. The frequency of these paints indicates that the Sikyatki priests attached considerable reverence to these colors, and that red and green played the same important part that they do today in ceremonial and divinatory practices.

The ancient Sikyatkians evidently deposited large stones on the grave in order to prevent animals from digging up the body. The only approach to a gravestone was a stone slab of rectangular outline, one edge of which had been cut into a terrace form and the face decorated with a symbolic figure of a rain cloud drawn in black outline. This stone can hardly be said to designate the name of the dead, but is more or less talismanic. The modern Tusayan Indians believe that the dead have certain occult powers over rain deities. "You have come to be a Rain God," is the import of their prayer to a deceased friend or

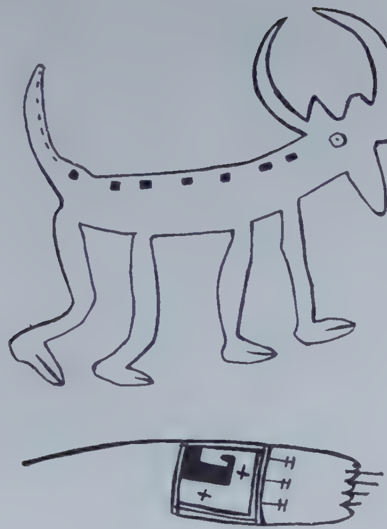
relative. Possibly a somewhat similar conception suggested the act of depositing the stone slab with a rain-cloud symbol in the prehistoric graves of Sikyatki.

Objects made of clay, or pottery, are by all odds the most artistic found in the Sikyatki cemeteries. It seems almost inconceivable that these symmetrical forms could have been made without knowledge of the potter's wheel, yet such is the truth. It is not too much to say that this collection contains objects more finely made and elaborately decorated than any ceramic work of any aboriginal tribe of North America, and that it will compare favorably with that of the cultured stocks of Central America. It is far superior to modern pottery made in adjacent pueblos in form, fineness of parts, and beauty of decoration. It is ornamented with an elaborate polychrome symbolic decoration, which differs in character from that of any modern pueblo near or remote. It is obvious, I believe, that the value of this large and beautiful collection of ornamented pottery lies primarily in the study of the symbolic decorations. These symbols, rarely duplicated, form a body of paleography which is an important index of ancient thought and feeling. Never before has such a great variety of ancient picture writing been taken from any one ruin of our Southwest, and as a consequence never has a larger amount of ancient pueblo pictography been placed before the student. If it were possible to interpret these pictures aright, our knowledge of ancient pueblo conceptions would be vastly enlarged.

Articles included in the designation "pottery" include rough, undecorated vessels made with coils of clay, which are readily traced on the exterior, and finely decorated smooth ware in which the appearance of the coils has been obliterated by polishing. The Sikyatkians made both kinds, apparently in the same way as do their descendants.

The former kind includes cooking pots, slipper-shape food receptacles, and water jars. In most instances these were blackened by use, but the coarse clay and embedded grains of sand were easily seen. The decorated pottery, on the other hand, was not blackened, and includes food basins, bowls, jars, vases, dippers, and other household ware. These may be classified according to character or color into three groups: (1) Black and white pottery, (2) yellow pottery, and (3) red ware.

The few specimens of black and white pottery in the collection are small bowls and jars, and were not made by Sikyatki potters, but were heirlooms from ancestors who derived them from cliff-house people, of whom this colored ware is characteristic. The red ware is likewise, I believe, intrusive in Sikyatki, and not a product of their skill, for it is characteristic of older rather than more recent times. The style of decoration of both black and white and red ware is mainly geometric designs, meanders, frets, key patterns, and spirals. Figures of animals, plants, and human beings are rare or unknown. The larger number of articles of pottery from Sikyatki are of the fine yellow ware, consisting



MOUNTAIN SHEEP.
(Food Bowl, No. 155473.)

MOUNTAIN LION.
(Food Bowl, No. 155476.)

HUMAN HAND.
(Exterior, Food Bowl, No. 155472.)

FORE LEG OF UNKNOWN ANIMAL.
(Exterior, Food Bowl, No. 155463.)

GERM GODDESS.
(Food Bowl, No. 155467.)

of almost all kinds of household utensils, food basins, jars, vases, medicine bowls, ladles, dippers, and cups.

The colors used in their decoration are red, brown, yellow, and black; and while many pieces are not decorated, these are exceptional, as the figures have in several instances been obliterated by age or wear in household use before burial. A method of ornamentation by spattering with pigment was popular, and details of some of the more elaborate figures are helped out by finely incised lines made after painting. The food basins were most elaborately decorated on their interiors; vases on the exterior. While in this respect cups were more like the former, dippers resembled the latter, when ornamentation was employed.

In considering the ornamental symbolism of the Sikyatki pottery, much aid can be had from present belief of the Indians, and some help may be derived from the character of modern symbolic decorations. Many symbols can be interpreted by these aids: more are unintelligible and the knowledge of the most intelligent of the living priests can shed only an uncertain light on some of the more elaborate figures employed in ornamentation. The paleography of old Tusayan is yet to be satisfactorily deciphered, and will tax the closest attention of the student.

For purposes of study, the symbolism of the Sikyatki pottery is grouped under three headings, according to the objects represented. I will briefly consider pictures from each of these groups, which may be designated as follows: (1) Figures of anthropomorphic gods and human beings; (2) figures of animals and plants; (3) geometric designs, terraces, bars, frets, and spirals.

The collection of bowls with figures of supernal and human beings are among the most interesting. The favorite organ of the human body to delineate was the hand, which is often beautifully drawn and decorated. As a rule, however, figures of animals are better made than those of men, and even more care seemed to have been given to purely conventional patterns than to accurate delineations of objects by which the artist was surrounded. Decorations often betray the antiquity of modern customs. As is well known the unmarried women of the modern Tusayan towns dress their hair in two coils, one over each ear, but after marriage their coiffure is of a wholly different character. In idols used in secret ceremonials the heads of female personages are indicated in the same way. The figures on several of the food basins from Sikyatki show that this peculiar method of dressing the hair is a very old one among these people. At the time of Coronado, in 1540, it was regarded so singular by the Spaniards, that one of the chignons used by the Indians was sent with other presents to the King. We now know that the fashion was older even than this, for Sikyatki was a ruin before Coronado's time, and no one can tell how long before pious reverence placed food basins with pictures of women whose hair was dressed in this fashion in Sikyatki graves. The hair dresser knows of few

styles of coiffure older than this which has persisted continuously for over four hundred years.

In the elaborate ceremonial system of both Pueblos and Navahoes, the rite of stick-swallowing is introduced, in which a stick is forced down the esophagus. In recent times, although sometimes attempted, this repulsive performance has degenerated into a clever deception on the part of the performer. If I am right in my interpretation of the decoration of one of the food vessels from Sikyatki, the habit is of great antiquity, for we have a figure represented on it of a person engaged in this revolting act, thus verifying a widely spread tradition that in old times the rite was practiced as a part of the Tusayan ritual. It is no longer performed at Walpi, but is reported from Zuñi and elsewhere.

One of the most important of all Tusayan mythic characters is a heroic personage called the Little War God. He was a cultus hero, and in early days is reputed to have freed the world of monsters which afflicted earth and sky. This heroic demigod is personated today, and his image occupies a convenient niche in many households. His constant emblem are two parallel lines of pigment drawn across the cheeks or breast, arms or legs.

This cultus hero is of no mean antiquity, but is as old as the time when Sikyatki was in its prime, for a picture of him shooting an unknown animal is drawn on a fragment of a food bowl. As in modern pictures, he bears on his face the two parallel marks which custom has prescribed must be worn by the God of War today. Students of the development of the arrow may find in this figure an indication of the kind of arrow the prehistoric warrior of Sikyatki used, viz, a long shaft with a short articulation to which the point is attached, as with certain other American tribes.

The ancient ceramic picture writing of Sikyatki gives, in many instances, something more than the bare symbolism of the mythological personage depicted. Of such a nature is a large fragment of a food basin from the graves of that ancient village, which is adorned with a representation of the Tusayan Harpy, Kwataka.

In existing folklore Kwataka or the Man Eagle was a bird-like monster, akin to the Thunderbird of other tribes of America, who afflicted the ancient people by carrying off their wives and devouring their children. His home was in the sky, and he is said to wear a garment covered with flint arrowheads.

The fragment in question represents the Man Eagle about to devour a problematical being. He is represented with the wings of a bird; his claws are eagle talons; his eye has the cross, symbol of the heart of the sky, or the star. But most interesting of all, he wears the flint-covered armor represented by four lozenge-shape figures which recall the Nahuatl symbol of the flint arrowpoint, techpatl.

As is known through Dr. Matthews' studies, the Navahoes likewise have a mythological being of similar import to that of the Hopi. By

WAR GOD, SHOOTING ANIMAL.
(Fragment Food Bowl, No. 155801.)

KWATAKA, EATING ANIMAL.
(Fragment Food Bowl, No. 155802.)

STICK SWALLOWER.
(Food Bowl, No. 155465.)

UNKNOWN REPTILE.
(Food Bowl, No. 155480.)

the discovery of this picture at Sikyatki, four centuries or more old, we are prepared to ask our Navaho students whether they can show an equal antiquity of this conception among the people they study, and to suggest the inquiry whether the Navahoes derived their idea from the Pueblos.

It is not without some deep-seated meaning that of all organs of the body, the Tusayan people of the ancient settlement at Sikyatki chose the human hand for decorative purposes. We know that oriental people do the same, and I have seen old Tusayan ware decorated with a human hand, but never such beautiful representations as that which occurs on the food vessels from Sikyatki. A figure of one of the best of these will serve to show the care with which this member was used for decorative purposes, but I must confess my inability to decipher the strange appendage which it shares with other decorative elements of very different character.

Mammalian animals are sparingly used as decorative forms, but among others may be mentioned the antelope, mountain lion, mountain sheep, and rabbit. Especially instructive is the figure of a puma drawn on the middle of the inside of a food vessel. The figure of a mountain sheep is one of the best in the collection. There seems hardly a doubt that these animal forms refer to mythic conceptions which are paralleled in the beliefs of the inhabited pueblos today.

Serpents and bizarre reptilians figure conspicuously in decorative animal pictography from Sikyatki, and betray in one or two instances the antiquity of a cult which is strong at Walpi today. Prominent among these is the great Plumed-head Serpent, the effigies and ceremonials pertaining to which at Walpi I have elsewhere described in detail. The serpent depicted on one of the food vessels is so close in its symbolism to this mythic being of Tusayan folklore that it is probable ophiolatry of a kindred sort was practiced in the ancient pueblo of Sikyatki where it was found.

One of the most bizarre figures of reptiles in Sikyatkian ceramic paleography adorns the inside of a reddish-colored food basin of rather coarse construction. This figure reminds one of the horned toad, but mythic rather than realistic elements preponderate in its delineation. The most striking anatomical feature is without doubt the serrated dorsal fin, but like the Plumed Serpent it bears on the head horns and feather appendages. There are two or more mythological reptilian personages recognized in the modern Tusayan olympus to which this picture may be referred, and it is not unlike the mythic lizard, who guards the traditional entrance to the under world, called the sipapû.

A fragment of pottery from Awatobi was found to have a head identical with that of this lizard from Sikyatki, showing that the cult was recognized in this neighboring village.

Of problematical reptilian forms, none are more conventional and highly symbolic than the decoration of another food basin. Here we

have the plumed head, the curved claws, the elongated snout, and the lizard-like body. I am ignorant of the proper identification of this animal, which perhaps is pardonable, for the best informed of living priests, whom I consulted, were also at a loss to explain the meaning of this highly conventionalized figure.

The tadpole and frog are constant decorative elements in Sikyatki picture writing as on modern ceremonial vessels, and no doubt had the same purport—the hastening of copious rains sorely needed in that arid land.

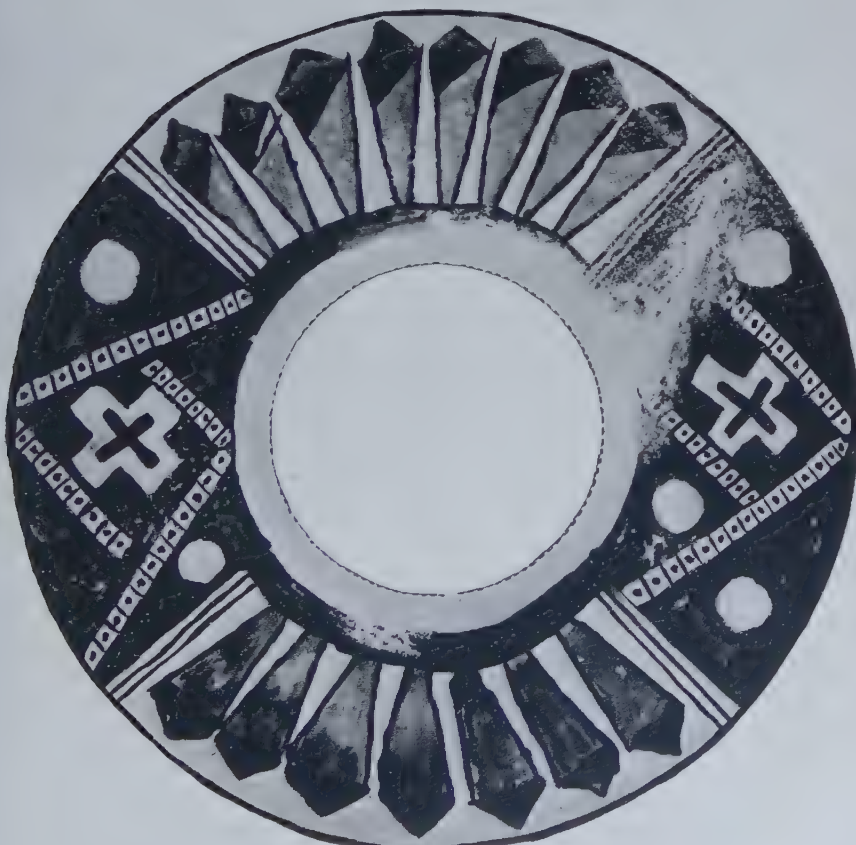
When we remember how large a part the bird and feathers play in modern symbolism, and how extensively they permeate the Tusayan ritual, it is not strange that by far the most widespread motif in Sikyatki ceramic decoration is referable to this element. The feather in many forms, mostly conventionalized, is represented again and again on basins, vases, and jars, and the bird is one of the most constant animals depicted in decorations.

The number of mythic birds with which the modern Tusayan mythology is crowded suggests caution in ascribing avian figures, of which there are many on Sikyatki pottery, to any one in preference to another of these supernaturals. We may rightly identify the pictures of several food basins as prehistoric representations of the High Sky Eagle, the dreaded Harpy, Kwataka. Two forms of feathers are recognized in decoration which have been determined from their position on the corresponding regions of these mythic birds. These are the tail feather and the breast feather, both of which are prescriptive in modern ceremonials.

It is customary at the present day for the priests in the performance of mysteries of their cults to use water from sacred springs for asperging and other purposes. This venerated liquid is brought to the sacred rooms with ceremonials, and is transported and kept in small jars during the rites. The custodians of this water tie a cotton string around the neck of these vessels, and to this encircling string attach others with appended feathers as prayer offerings. A similar custom with modification was current at Sikyatki, except that instead of tying the strings to the sacred jars, the feather was used as a decorative element, and carefully painted on the side of the vase or jar.

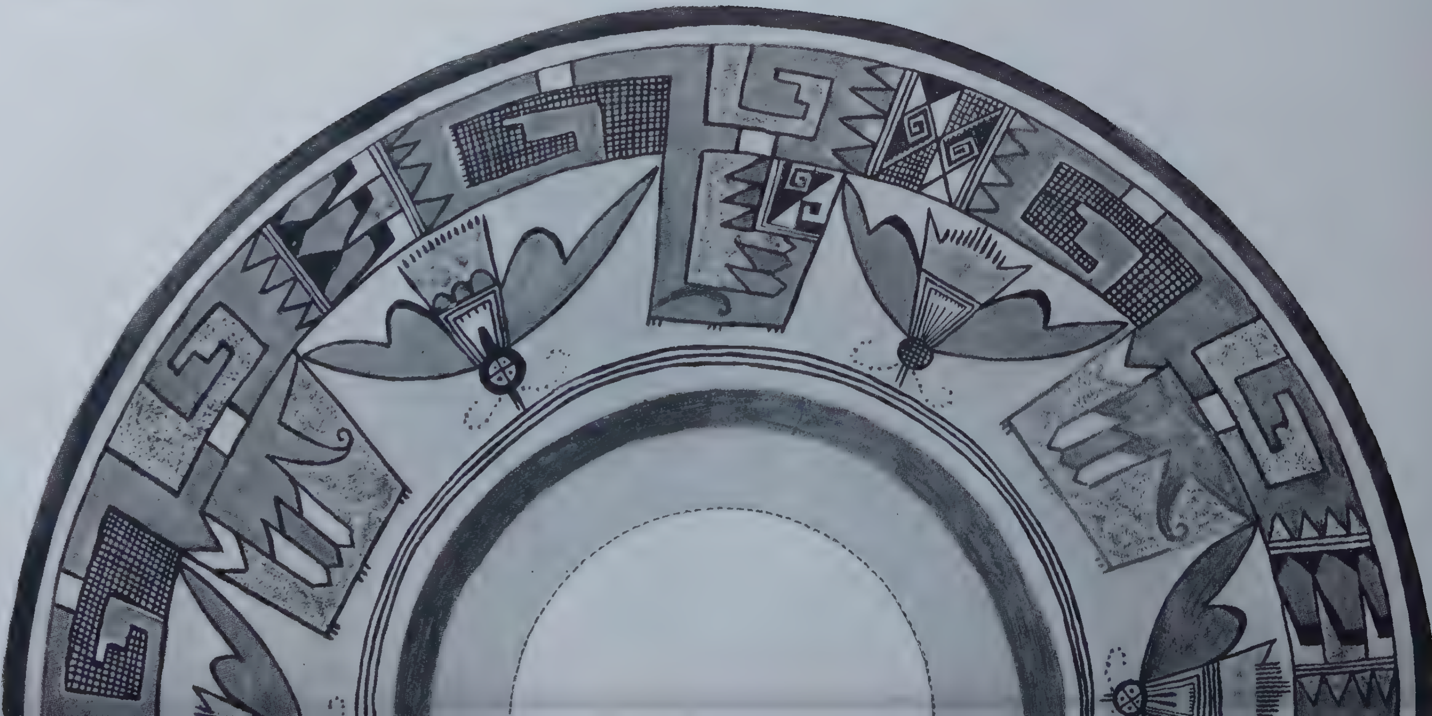
The use of the dragon fly and moth or butterfly symbols has come down to the modern priests from a remote antiquity, and no doubt at Sikyatki, as at Walpi today, the former was an emblem of moisture; the latter of fecundity. One of the most regularly formed and beautifully decorated of these ancient vases is adorned with six figures of moths, and it is interesting that during all the lapse of time since a clever Sikyatki woman painted it, the same signs of male and female have survived. A well-drawn figure of a butterfly appears on the interior of several food basins, and it is instructive to notice with what care the antennæ were depicted.

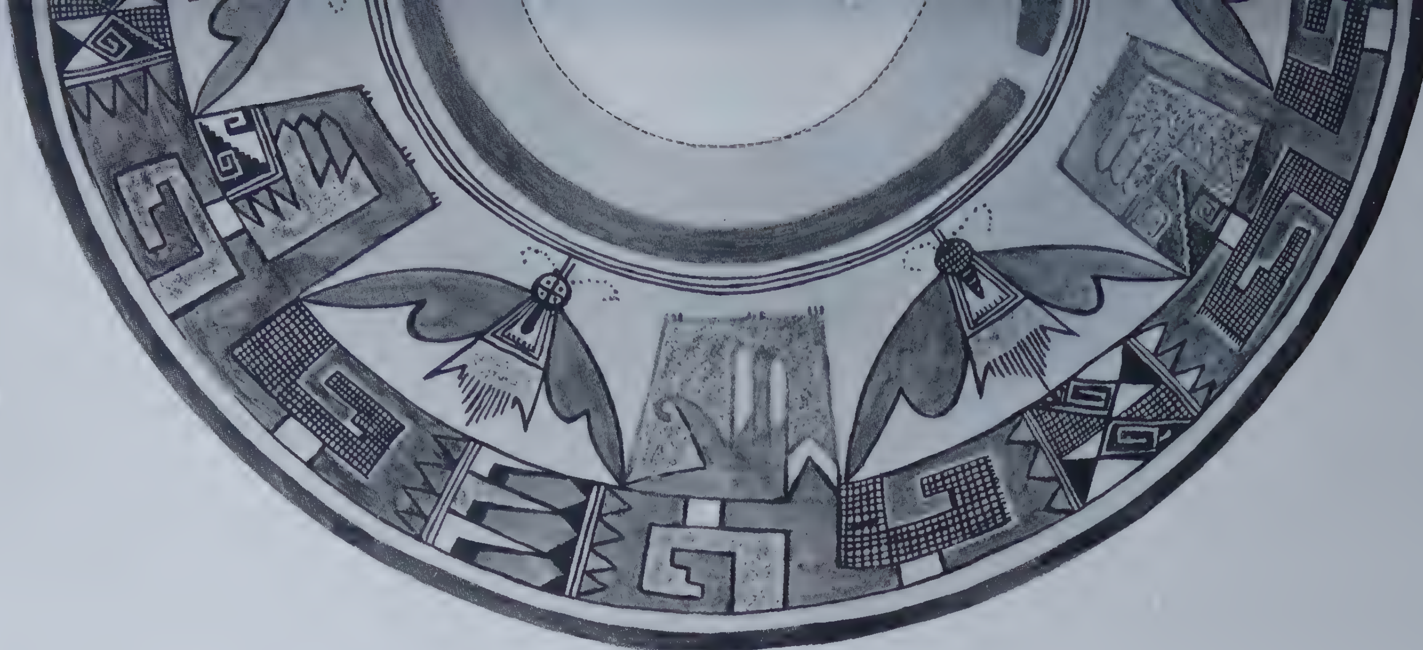
VASE WITH DEPENDENT FEATHER ORNAMENT.
(No. 155711.)



VIEW OF FEATHER DECORATIONS ON UPPER SURFACE OF VASE.
(No. 155697.)

UPPER SURFACE OF VASE WITH BIRD DECORATIONS.
(No. 165690.)





Upper Surface of a Vase with Butterfly Decorations.
(No. 155681.)

The ancient artists of Sikyatki recognized the flower as a decorative element, but strangely enough, overlooked the leaf, which later came, through foreign influence, to play such an important part in ornamental possibilities. I find no instance in all decorations of the adaptation of leaves to the adornment of ceramic productions by the Tusayan ancients.

Of strange conceptions, none are more foreign to Aryan habits of thought than that of a feathered rainbow, but such a tenacious hold had this on the ancient potters of Sikyatki that they reproduced it in figures in many of their pictures.

Geometrical figures form by far the majority of decorative elements of the ancient pottery of Sikyatki. We have the key and terrace patterns, spirals, frets, and scrolls. In their artistic productions, all the elements of crosshatching, rectangular figures, stars, and circles, were made to contribute to the ornamentation of their ceramics. Many of these passed into conventional symbols, many were purely decorative, but all testify the degree of artistic feeling which the ancient potters of this town possessed. As works of esthetic feeling no less than objects of scientific interest, the revelations of the Sikyatki cemeteries are of greatest importance in the history of the evolution of geometrical ornament.

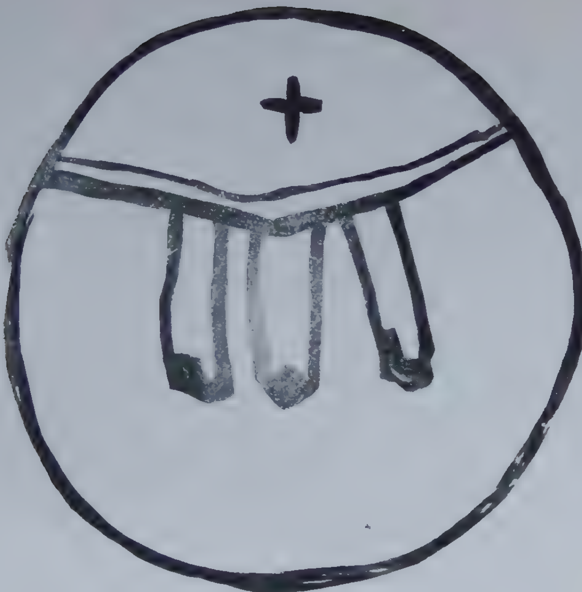
Many of the encircling bands decorating vases and food basins are broken at one point in their course. This break, ordinarily called the line of life, is found in ancient pottery from the mounds of the Gila and Salt rivers in southern Arizona, and is common in old Cibolan ware. Its meaning is symbolic, and probably the same as in modern ware as pointed out by others.

Many of the food basins and some vases have parallel bars drawn at intervals exteriorly on the rims or lips. These lines, two or three in number, are sometimes so arranged as to form the letter H and recall similar lines, four in number, made with sacred meal on the fuor walls of a room during certain secret rites. This mode of decoration was likewise a widespread one in ancient pueblo pottery, and is at times followed by modern potters.

Of encircling lines, none are more problematical, from the point of view of interpretation, than those with bars or dots at intervals, so common on the exterior of many food basins. While distinctly conventional, these decorative elements have a deeper symbolic meaning, which would require many pages to elaborate.

The character and decoration of pottery from the two ruins, Awatobi and Sikyatki, are very close to each other, and markedly different from modern ware still manufactured at Hano and Walpi, only 3 miles distant from the latter ruin. These characteristics of resemblance are common features of all ancient Tusayan ceramics. In other words, modern pottery has greatly deteriorated, old decorative motifs have passed out of use, and, what is more significant, new symbolic decorative

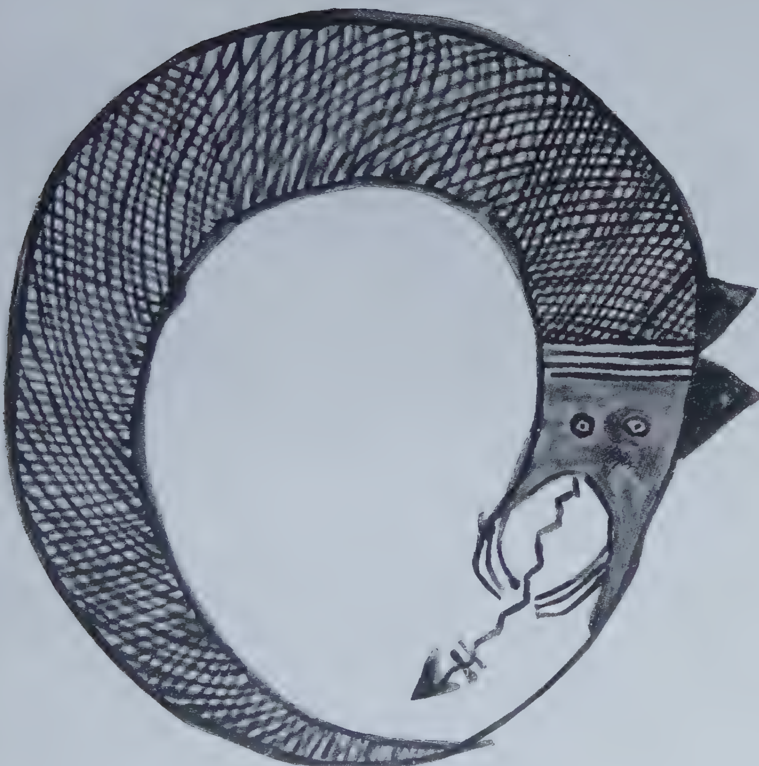
elements have replaced the ancient. The answer to the question, whence came these innovations, is outside the limits of this report. The similarities of the ancient pottery found in Tusayan ruins far distant from each other implies a homogeneity in the people of Tusayan which was indicative of closer kinship. Since the overthrow of Sikyatki and Awatobi, the consanguinity of the pueblos has been changed by assimilation of foreign blood from other pueblos of Arizona and New Mexico, as we know also from documentary and legendary history. Groups of peoples from the Rio Grande pueblos have fled to Tusayan, bringing their pottery with them, thus introducing other decorative motifs as well as novel rituals and mythologies. It has thus resulted that the ornamentation now used by the Tusayan potters is radically different from that of the ancients.



FEATHER RAINBOW.
(Food Bowl, No. 155509.)

FLOWER DECORATION.
(Food Bowl, No. 155575.)

UNKNOWN REPTILE.
(Food Bowl, No 155479.)



PLUMED SERPENT.
(Food Bowl, No. 155482.)

MAN-EAGLE.
(Food Bowl, No. 155488.)

HUMAN HAND.
(Food Bowl ½ nat. Size.)

MYTHIC BIRD.

(Food Bowl ½ nat. Size.)

UNKNOWN SYMBOL BIRD(?)

(Food Bowl ½ nat. Size.)

RACE AND CIVILIZATION.[1]

By Prof. W. M. Flinders Petrie, D. C. L., LL. D.

In a subject as yet so unmapped as anthropology there is more room for considering different points of view than in a thoroughly organized and limited science. The future structure of this science depends largely on the apprehension of many different modes of treating it. The time has not yet come when it can be handled as a whole, and therefore at present we may frankly consider various questions from an individual standpoint, without in the least implying that other considerations should be taken into account. It is only by the free statement, however one-sided, of the various separate views of the many subjects involved in such a science that any comprehensive scheme of its organization can ever be built up. In remarking, therefore, on some branches at present I shall not attempt a judicial impersonality, but rather try to express some views which have not yet been brought into ordinary currency.

Elaborate definitions of anthropology have been formulated, but such are only too liable to require constant revision as fresh fields of research are added to the domain. In any new country it is far safer to define its limits than to describe all that it includes, and all that can yet be done in anthropology is to lay down the "sphere of influence," and having secured the boundaries, then develop the resources at leisure. The principle bordering subjects are zoology, metaphysics, economics, literature, and history. So far as these refer to other species, as well as to man, or to individuals rather than to the whole race, they stand apart as subjects; but their relation to the human species as such is essentially a part of anthropology. We must be prepared, therefore, to take anthropology more as a study of man in relation to various and often independent subjects than as an organic and self-contained science. Human nature is greater than all formulæ; and we may as soon hope to compact its study into a logical structure, as to construct an algebraical equation for predicting its course of thought.

[1] Address by Prof. W. M. Flinders Petrie, D. C. L., LL. D., president of the section of anthropology, at a meeting of the British Association for the Advancement of Science, at Ipswich, 1895. Reprinted from the Report of the British Association for 1895, pp. 816–824.

Two of the commonest and most delightful elastic words in the subject may be looked at once more—"race" and "civilization." The definition of the nature of race is the most requisite element for any clear ideas about man. Our present conception of the word has been modified recently more than may be supposed by our realizing the antiquity of the species. When only a few thousand years had to be dealt with nothing seemed easier or more satisfactory than to map out races on the assumption that so many million people were descended from one ancestor and so many from another. Mixed races were glibly separated from pure races, and all humanity was partitioned off into well-defined divisions. But when the long ages of man's history and the incessant mixtures that have taken place during the brief end of it that is recorded come to be realized the meaning of "race" must be wholly revised. And this revision has not yet taken effect on the modes of thought, though it may have demanded the assent of the judgment. The only meaning that a "race" can have is a group of persons whose type has become unified by their rate of assimilation and affection, by their conditions exceeding the rate of change produced by foreign elements. If the rate of mixture exceeds that of assimilation, then the people are a mixed race, or a mere agglomeration, like the population of the United States. The greatest problems awaiting solution are the conditions and rate of assimilation of races, namely, what period and kind of life is needed for climatic and other causes to have effect on the constitution and structure, what are the causes of permanence of type, and what relative powers of absorption one race has over the other. Until these problems are reduced to something that can be reasonably estimated we shall only grope in the dark as to all racial questions.

How, then, can these essential problems be attacked? Not by any study of the lower races, but rather by means of those whose history is best recorded. The great mode of isolation on which we can work is religious difference, and oppressed religious minorities are the finest anthropological material. The first question is (given a mixture of various races in approximately known proportions, isolated, and kept under uniform conditions), how soon does uniformity of type prevail, or what proportions of diversity will be found after a given number of generations? A perfect case of this awaits study in the Copts, who have, by monogamy and the fanaticism of a hostile majority, been rigorously isolated during twelve hundred years from any appreciable admixture, and who before this settling time were compounded of eight or ten different races, whose nature and extent of combination can be tolerably appraised. A thorough study of the present people and their forefathers, whose tombs of every age provide abundant material for examination, promises to clear up one of the greatest questions—the effect of climate and conditions on assimilating mixed peoples. The other great problem is, how far can a type resist changes of conditions,

provided it be not mixed in blood so as to disturb the equilibrium of constitution? This is to be answered by the Jews and the Parsis. As with the Copts, an oppressed religious minority has no chance of mixture, as all mixed marriages are abhorrent to its exclusiveness and are at once swept into the hostile majority. The study is, however, far more difficult, owing to the absence of such good conditions of the preservation of material. But nothing could throw so much light on this as an excavation of some Jewish cemeteries of a thousand years or so ago in various European countries, and comparison of the skeletons with the proportions of the Jews now living. The countries least affected by the various proscriptions and emigrations of the race would be the proper ground for inquiry. When these studies have been made we shall being to understand what the constants of a race really are.

We will now look at another word which is incessantly used—"civilization." Many definitions of this have been made, from that of the Turk drinking champagne, who remarked about it that "after all, civilization is very nice," up to the most elaborate combinations of art and science. It is no doubt very comfortable to have a word which only implies a tendency, and to which everyone can assign his own value; but the day of reckoning comes, when it is brought into arguments as a term. Civilization really means simply the art of living in a community, or the checks and counterchecks, the division of labor, and the conveniences that arise from common action when a group of men live in close relation to each other. This will perhaps be objected to as including all, or nearly all, mankind in its scope. Quite true; all civilization is relative and not absolute.

We shall avoid much confusion if we distinguish high and low types of civilization, and also perfect and imperfect civilization. Like organisms, we may have a low type of civilization very perfect in its structure, capable of endless continuance, and of great shocks without much injury. Such are some of the civilizations of the African races who have great orderliness and cleanliness of arrangements, and are capable of active recuperation after warfare, without any internal elements of instability. Again, some low types are very imperfect, and can only exist by the destruction of others, while any severe shock destroys their polity; the governments which only exist by raids and plunder, such as that of the Zulus, illustrate this. Turning to high types of civilization, we may see them perfect or imperfect. Countries of financial stability, not undergoing any rapid organic changes, are the more perfect in type; while those deeply in debt and in continual revolution have but imperfect civilization, of however high a type it may be. With these types of all variety, from the highest complexity to the lowest simplicity, and of all degrees of perfection, or stability and completion, in any given level of complexity—with these distinctions some of the vagueness of verbal usage may perhaps be avoided.

Turning now from words to things, we may perhaps see some ground for further consideration in even one of the best elaborated departments.

In the much vexed questions of skull measurements, the paucity of clearly defined racial characteristics may make us look more closely as to whether we are working on an analytic or empirical method. In any physical problem the first consideration is the disentangling of variables and isolation of each factor for separate study. In skulls, however, the main measures are the length, which is compounded of a half dozen elements of growth, and the breadth and height, each the resultant of at least three elements. Two skulls may differ altogether in their proportions and forms, and yet yield identical measures in length, breadth, and height. How can any but empirical results be evolved from such a system of measurement alone?

A departure from this mechanical method has appeared in Italy last year by Professor Sergi. He proposes to classify skulls by their forms—ellipsoid, pentagonoid, rhomboid, ovoid, etc. This, at least, takes account for the obvious differences which the numerous measurements wholly ignore; and if skulls were crystals, divisible into homogeneous classes, such a system would work, only, like all organic objects, they vary by infinite gradation.

What, then, lies behind this variety of form? The variety of action in the separate elements of growth. Sergi's ellipsoid type means slight curvatures, with plenty of frontal growth. His pentagonoid means sharper curvatures. His rhomboid means sharp curvatures, with small frontal growth. And so in each class we have not to deal with a geometrical figure, but with varying curvatures of the center of each plate of the skull and varying extent of growth from the centers.

The organic definition of a skull must depend on the statement of the energy and direction of each of the separate elements out of which it is built. The protuberances or eminences are the first point to notice. They record in their curves the size of the head when it attained rigidity in the centers of growth. Every person bears the fixed outline of parts of his infant skull. Little, if any, modification is made in the sharpness of the curves between infancy and full growth; perhaps the only change is made in course of the thickening of the skull. Hence, the maximum radius of curvature of each plate of the skull is a most radical measurement, as implying early or late final ossification. In higher races finely rounded skulls with slight curvatures are more often found; and this agrees with the deferred fixation of the skull pointed out by the greater frequency of visible sutures remaining, both effects being probably due to the need of accommodating a more continued growth of the brain. The length of growth of each plate from its center in different directions regulates the entire form of the skull. The maximum breadth being far back implies that the parietals grow mostly toward the frontal, or vice versa. The top being ridged means that the

parietals grow conical and not spherically curved, and hence meet at an angle.

It seems, therefore, that looking at the question as a physical problem, we are far more likely to detect racial peculiarities in the separate data of the period of fixation of the skull, and of the amount of growth in different directions, than by any treatment of gross quantities which are compounded out of a number of variables. The practical development of such a view is the work of the embryologist; here we only notice a principle of treatment of a most complex question, which seems to have too often been dealt with as if it were as simple as the definition of a crystal.

When we next turn to look at the works of man, it seems that the artistic side of anthropology has hardly been enough appreciated. In the first place, the theory of art has been grounded more assuredly by anthropological research than by all the speculations that have been spun. The ever-recurring question, "What is art?" whether in form or in literature, has been answered clearly and decidedly. When we contrast a row of uninteresting individualities with the ideal beauty and expression of a composite portrait compounded from these very elements, we are on the surest ground for knowing how such a beautiful result is obtained. In place of the photographic verity of the person, we have the artistic expression of a character. Whatever is essential remains, and is strengthened; whatever is transient and unimportant has faded away. No one can look, for instance, at the composite heads of Jewish boys and their individual components, published some years ago in the Anthropological Journal, without feeling the artistic beauty of the composite and the unbalanced characters of the individuals. What the camera does mechanically by mere superposition, the artist does intelligently by selection. The unimportant, unmeaning phases of the person, the vacuities of expression, the less worthy turns of the mind are eliminated, whether in form or in words, and the essence of the character is brought out and expressed. Such is the theory of artistic expression which anthropology has established on a sure basis of experiment, and which is thus proved to be neither fanciful nor arbitrary, but to be a truly scientific process.

And as anthropology has thus aided art, the converse is also true—art is one of the most important records of a race. Each group of mankind has its own style and favorite manner, more particularly in the decorative arts. A stray fragment of carving without date or locality can be surely fixed in its place if there is any sufficient knowledge of the art from which it springs. This study of the art of a people is one of the highest branches of anthropology and one of the most important, owing to its persistent connection with each race. No physical characteristics have been more persistent than the style of decoration. When we see on the Celtic work of the period of La Tène, or on Irish carvings, the same forms as on mediæval ironwork, and on

the flamboyant architecture of France, we realize how innate is the love of style, and how similar expressions will blossom out again from the same people. Even later we see the hideous C-curves, which are neither foliage nor geometry, to be identical on late Celtic bronze, on Louis XV carvings, and even descending by imitation into modern furniture. Such long descent of one style through great changes of history is not only characteristic of Celtic art, but is seen equally in Italy. The heavy, stiff, straight-haired, staring faces of the Constantine age are generally looked on as being a mere degradation of the imported Greek art; but they are really a native revival, returning to old Italian ideals, so soon as Greek influence waned. In the Vatican is an infant Hercules of thorough Constantinian type, yet bearing an Etruscan inscription, proving the early date of such work. Farther East the long persistent styles of Egypt, of Babylonia, of India, of China, which outlived all changes of government and history, show the same vitality of art. We must recognize, therefore, a principle of "racial taste," which belongs to each people as much as their language, which may be borrowed like languages from one race by another, but which survives changes and long eclipses even more than language. Such a means of research deserves more systematic study than it has yet received.

But if we are to make any wide comparisons and generalizations, a free study of material is essential, and the means of amassing and comparing work of every age is the first requisite. This first requisite is unhappily not to be found in England. The conception of collecting material for the study of man's history has as yet little root, and struggles to find a footing between the rival conceptions of the history of art and the life of modern man. The primary difficulty is the character of the museum accommodation at present provided. This is all of an elaborate and expensive nature, in palatial buildings and on highly valued sites. To house the great mass of objects of either ancient or modern peoples in such a costly manner is impracticable, and hence, at present, nothing is preserved but what is beautiful, strange, or rare. In short, our only subjects of study are the exceptional and not the usual products of races. The evil traditions of a "collection of curiosities" still brood over our materials, and until we face the fact that for study the common things are generally more important than the rare ones, anthropology must remain much as chemistry would if we were restricted to the study of pretty colors and sweet scents.

Until we have an anthropological storehouse on a great scale we can not hope to preserve those materials which are now continually being lost to study for lack of reasonable accommodation. Such a storehouse should be on the cheapest ground near London, built in the simplest weather-tight fashion, and capable of indefinite expansion without rearrangement or alteration of existing parts. It should contain no baits for burglars, all valuable objects being locked up in the security of the British Museum, to which such a storehouse would form a

succursal, greatly relieving the present overcrowded state of many departments. To such a storehouse for students all that does not serve for public education, or that is not portable or of much saleable value, should be consigned. There the piles of architectual fragments which are essential for study, but are useless to show the public, should be stacked in classified order. There the heaps of pottery of ancient and modern races should all be arranged to illustrate every variety of form and style. There the series of entire tombs of other races and of our own should be set out in their original arrangement, as in the Bologna Museum. There whole huts, boats, etc., could be placed in their proper order and sequence, while photographs of the showy educational specimens and valuable in the public museums could fill their places in the arrangement. That such a storehouse is needed may be illustrated by a collection gleaned in a few months' work this year. It represents the small products of a little village and a cemetery of a new race in Egypt. But there is no possibility of keeping such a collection together in any London museum, and but for the new Ashmolean Museum at Oxford having been lately built with a wide view to its increase, it is doubtful if in any place in England such a collection could be kept together. What happens to one excavator this year may happen to a dozen excavators per annum in a generation or two hence, and so long as space is not available to preserve such collections when they are obtained, invaluable material is being irrevocably wasted and destroyed.

Besides the theoretical and scientific side of anthropology, there is also a very practical side to it which has not received any sufficient development as yet. Anthropology should in our nation be studied first and foremost as the art of dealing with other races. I can not do better than quote a remark from the address of our previous president, Gen. Pitt Rivers, a remark which has been waiting twenty-three years for further notice. He said: "Nor is it unimportant to remember that anthropology has its practical and humanitarian aspect; and that as our race is more often brought into contact with savages than any other, a knowledge of their habits and modes of thought may be of the utmost value to us in utilizing their labor, as well as in checking those inhuman practices from which they have but too often suffered at our hands."

The foremost principle which should be always in view is that the civilization of any race is not a system which can be changed at will. Every civilization is the growing product of a very complex set of conditions, depending on race and character, on climate, on trade, and every minutia of the circumstances. To attempt to alter such a system apart from its conditions is impossible. For instance, whenever a total change is made in government, it breaks down altogether, and a resort to the despotism of one man is the result. When the English constitution was swept away Cromwell or anarchy was the alternative. When the French constitution was swept away Napoleon was the only salvation

from anarchy. And if this is the case when the externals of government alone are altered, how much more is it the case if we attempt to uproot the whole of a civilization and social life? We may despotically force a bald and senseless imitation of our way on another people, but we shall only destroy their life without implanting any vitality in its place. No change is legitimate or beneficial to the real character of a people except what flows from conviction and the natural growth of the mind. And if the imposition of a foreign system is injurious, how miserable is the forcing of a system such as ours, which is the most complex, unnatural, and artificial that has been known—a system developed in a cold country, amid one of the hardest, least sympathetic, and most self-denying and calculating of all peoples of the world. Such a system, the product of such extreme conditions, we attempt to force on the least developed races, and expect from them an implicit subservience to our illogical law and our inconsistent morality. The result is death; we make a deadhouse and call it civilization. Scarcely a single race can bear the contact and the burden. And then we talk complacently about the mysterious decay of savages before white men.

Yet some people believe that a handful of men who have been mutilated into conformity with civilized ideas are better worth having than a race of sturdy, independent beings. Let us hear what becomes of the unhappy products of our notions. On the Andaman Islands an orphanage, or training school, was started and more than forty children were reclaimed from savagery, or torn from a healthy and vigorous life. These were the results: "Of all the girls two only have continued in the settlement, the other survivors having long since resumed the customs of their jungle homes. - - - Physically speaking, training has a deteriorating effect, for of all the children who have passed through the orphanage probably not more than ten are alive at the present time, while of those that have been married two or three only have become parents, and of their children not one has been reared."[1] Such is the result of our attempts on a race of low but perfect civilization, whom we eradicate in trying to improve them.

Let us now turn to our attempts on a higher race, the degenerated and Arabized descendants of a great people—the Egyptians. Here there is much ability to work on, and also a good standard of comfort and morality, conformable to our notions. Yet the planting of another civilization is scarcely to be borne by them. The Europeanized Egyptian is in most cases the mere blotting paper of civilization, absorbing what is most superficial and undesirable. The overlaying of a French or English layer on a native mind produces only a hybrid intellect, from which no natural growth or fertility can be expected. Far the more promising intellects are those trained by intelligent native teachers, where as much as can be safely assimilated has grown naturally as a development of the native mind.

Yet some will say, why not plant all we can? What can be the harm

[1] E. H. Man, "On the Andaman Island," Anthrop. Jour., XIV, 265.

of raising the intellect in some cases if we can not do it in all? The harm is that you manufacture idiots. Some of the peasantry are taught to read and write, and the result of this burden which their fathers bore not is that they become fools. I can not say this too plainly; an Egyptian who has had reading and writing thrust on him is, in every case that I have met with, half-witted, silly, or incapable of taking care of himself. His intellect and his health have been undermined and crippled by the forcing of education. With the Copt this is quite different; fathers have been scribes for thousands of years, and his capacity is far greater, so that he can receive much more without deterioration. Observation of these people leads to the view that the average man can not receive much more knowledge than his immediate ancestors. Perhaps a quarter or a tenth more of ideas can be safely put into each generation without deterioration of mind or body; but, at the best, growth of the mind can in the average man be but by fractional increments in each generation, and any large increase will surely be deleterious to the average mind, always remembering that there are exceptions both higher and lower. Such a result is only what is to be expected when we consider that the brain is the part of man which develops and changes as races reach a higher level, while the body remains practically constant through ages. To expect the brain to make sudden changes of ability would be as reasonable as to expect a cart horse to breed racers, or a greyhound to tend sheep. Man mainly develops by internal differences in his brain structures, as other animals develop by external differences in bones and muscles.

What, then, it may be asked, can be done to elevate other races? How can we benefit them? Most certainly not by Europeanizing them. By real education, leading out the mind to a natural and solid growth, much can be done; but not by enforcing a mass of accomplishments and artificialities of life. The general impression in England is that reading, writing, and arithmetic are the elements of education. They might be so to us "in the foremost files of time," but they assuredly are not so to other races. The complex ideas of connecting forms and sounds is far too great a step for many brains, and when we succeed, to our delight, in turning out finished readers, Nature comes in with the stern reply, "Of their children not one has been reared." Our bigoted belief in reading and writing is not in the least justified when we look at the mass of mankind. The exquisite art and noble architecture of Mykenæ, the undying song of Homer, the extensive trade of the Bronze Age, all belonged to people who never read or wrote. At this day some of my best friends, in Egypt, are happily ignorant of such accomplishments, and assuredly I never encourage them to any such useless waste of their brains. The great essentials of a valuable character—moderation, justice, sympathy, politeness and consideration, quick observation, shrewdness, ability to plan and prearrange, a keen sense of the uses and properties of things—all these are the qualities on which I value my Egyptian friends, and such qualities are what

should be evolved by any education worth the name. No brain, however humble, will be the worse for such education which is hourly in use; while in the practical life of a simple community the accomplishments of reading and writing are not needed for perhaps a week or a month at a time. The keenest interest is taken by some races, and probably by all, in geography, modes of government, and social systems; and in most countries elements of hygiene and improvements in the dwellings and arts of life may be taught with the best results. There is, therefore, a very wide field for the education of even the lowest races, without throwing any great strain on the mental powers. And it must always be remembered that memory is far more perfect where a less burden of learning is thrown on the mind, and ideas and facts can be remembered and brought into use more readily by minds unstrained by artificial instruction.

The greatest educational influence, however, is example. This is obvious when we see how rapidly the curses of our civilization spread among those unhappily subjected to it. The contact of Europeans with lower races is almost always a detriment, and it is the severest reflection on ourselves that such should be the case. It is a subject which has given much room for thought in my own dealings with the Egyptian peasant to consider how this deleterious effect is produced and how it is to be avoided. Firstly, it is due to carelessness in leaving temptations open to natives, which may be no temptations to ourselves. To be careless about sixpences is as demoralizing to them as a man who tossed sovereigns about the street would be to us. Examples of carelessness in this point are among the worst of influences. Another injury is the inducement to natives to imitate the ways and custom of Europeans without reason. Every imitation, as mere imitation, is a direct injury to character; it teaches a man to trust to some one else instead of thinking for himself; it induces a belief in externals constituting our superiority, while foresight and self-restraint are the real roots of it; and it destroys all chance of any real and solid growth of character which can flourish independently. A native should always be discouraged from any imitation, unless he attempts it as an intelligent improvement on his own habits. Another sadly common evil is the abuse of power, which lowers the sense of self-respect, of honor, and of honesty which can be found in most races. If a man or a government defrauds, it is but natural to the sufferer to try to recompense himself by any means available; and thus an interminable system of reprisals is set up. Such is the chronic state of the East at present among the more civilized races. The Egyptians are notorious for their avarice, and are usually credited with being inveterate money grabbers; yet no sooner do they find that this system of reprisals is abandoned and strict justice maintained, than they at once respond to it; and I may say that when confidence has once been gained it is almost as common to find a man dispute an account against his own interest as for himself, and scarcely ever is any attempt made at false statements or

impositions. Such is the healthy response to straightforward dealing with them.

It is therefore in encouraging a healthy growth of all that is worthy and good in the existing systems of lower civilization, in repressing all mere imitations and senseless copying, and in proceeding on a rigorously just yet genial course of conduct, that the safe and true line lies for intercourse with inferior or different civilizations.

And, lastly, the question comes home to us, In what way is this practical anthropology to be fostered? It is so essentially important to us as a race that we should take good care that it is understood. Whether it be a question of interference with the customs of higher races, as the Hindu, or of lower savages, as the Australian, momentous questions may often depend on public opinion among a mass of people in England who have no conception at present of the race with whom they are dealing. And still more needful is it for those who take part abroad in the government of other races to have a wide view of the character of various civilizations. Until the present generation, there have been two great educative influences on the view of life taken by Englishmen—the Old Testament and the classics. So long as a boy had his ideas formed in contact with Oriental polygamy and Greek polytheism, he was not in danger of undue narrowness in dealing with the Muslim or the Hindu; but with the pressure of modern requirements both of these excellent views of other civilizations are being crowded out, and we meet men now to whom the world's history began when they were born. There is great danger in such ignorance. All the painful and laborious experiments in social and political problems during past ages are ignored, rash trials are made on lines which have been repeatedly proved to be impossible, and the real advance in any direction is thwarted by useless repetitions of the well-known failures of the past.

It is the business of anthropology to step in and make a knowledge of other civilizations a part of all decent education. In this direction our science has a most important field before it, at least as valuable as geography and history, and far more practical in developing ideas than many of the smatterings now taught. To present a view of another civilization, we require to give an insight into the way of looking at the world, the modes of thought, the aims of life, the checks and counter-checks on the weaknesses of man, and the construction of society and of government in each case. The origin and utility of the various customs and habits need to be pointed out, and in what way they are reasonable and needful to the well-being of the community. And, above all, we ought to impress on every boy that this civilization in which he grows is only one of the innumerable experiments of life that has been tried; that it is by no means the only successful one, or perhaps not the most successful, that there has been; that there are many other solutions of the problems of community and culture which are as good as our own, and that no one solution will fit a different race, climate, or set of conditions.

How such a sense of proportion in the world is to be attained, and what course of instruction will eradicate political fanaticism and plant a reasonable tolerance of other forms of civilization is the problem before us as practical anthropologists. The highest form of this perception of other existence is reached in the best history—writing or fiction—which enables the reader to strip himself for the time of his prejudices and view of life and reclothe the naked soul with an entirely different personality and environment. Very few writers, and those only in rare instances, can reach this level. It needs consummate knowledge, skill, sympathy, and abandon in the writer, and if without these, it is neither accurate nor inspiring. The safer course is to carefully select from the best literature of a civilization, and explain and illustrate this so as to leave no feature of it outside of the reason and feelings of the reader. Here we run against the special bigotry of the purely classical scholar, who looks on ancient literature as a peculiar preserve solely belonging to those who will labor to read it in its original dress. No one limits an acquaintance with Hebrew, Egyptian, or Arabic authors to those who can deal with those tongues, and Greek and Latin authors ought to be as familiar to the English reader as Milton or Macaulay. To say that because it is impossible in a business education to give several years to a working knowledge of ancient languages, that therefore all thought written in those languages shall be a sealed book, is pedantry run mad. A few months or even weeks on translation will at least open the mind and give an intelligent sense of the variety and the standpoint of the intellect of the past. And such a course is certainly better than the total ignorance which now prevails on such lines where the classics are not taught.

What seems to be the most practical course would be the recognition of civilization or social life as a branch of general reading to be stimulated in schools and encouraged by subsequent inquiry as to the extent to which it is followed and understood, without making it an additional fang of the examination demon.

The books required for such reading should cover the life of Greece, Rome, Babylon, Egypt, and Mexico in ancient times; and China, India, Persia, Russia, Spain, and one or two low civilizations, such as the Andamans and the Zulus, in modern times. Neither histories nor travels are wanted for this purpose, but a selection of the literature which shall most illustrate the social life and frame of the community, with full explanation and illustrations. We need not to excite wonder, astonishment, or disgust, but rather to enable the reader to realize the daily life, and to live in the very minds of the people. Where no literature is available, a vivid study of the nature of the practical working of their civilization should take its place.

Such is the practical scope of anthropology in our daily life, where it needs as much consideration and will exercise as great an influence as any of the other subjects dealt with by this Association.

POLYCHROMY IN GREEK STATUARY.[1]

By MAXIME COLLIGNON.

In the days when Hittorff had proven conclusively in his writings that Greek architects constantly employed polychromy, an archæologist, a determined adversary of the new theory, traveled all over Greece, resolved to see nothing that could be opposed to his views. One of his followers had climbed to the cornice of a temple, and while exploring it, the following dialogue was heard: "Do you find any traces of color?" "Yes!" "Come down instantly!" Unless we employ the same method, it is very difficult nowadays to doubt that the Greeks painted their statues. The question is a matter of fact, and arguments drawn merely from æsthetics, or from sentiment, can not prevail against abundant testimony.

Not only do excavations in Greece, in Olympia, Athens and Delphi furnish us many an imposing series of sculptures, uninjured by indiscreet restoration and still preserving, as they came forth from the soil, traces, and sometimes actually startling traces, of painted decorations, but the catalogues of the great museums of Europe report periodically among their new acquisitions Greek marbles on which the practiced eye very quickly discovers unmistakable vestiges of painting. And who could possibly measure the harm that has been done in this respect by the fatal mania of so-called restoration and of thorough cleansing, from which we are now happily delivered? The principle of polychromy itself is no longer contested. The account of former controversies would now hardly offer more than one single kind of interest. This would be to see how a prejudice gradually declined that had been born in the days of the Renaissance, defended in the name of modern æsthetics, and yielding, step by step, and with frequent rebellions, to the reality of facts. But though on this point all discussion is at an end, yet the question remains open. In fact, it is evident that polychromy has been applied in various ways, and that during the five or six centuries in which Greek art has enjoyed an independent life, the progress made in technical matters, as well as in style, has modified the rules which controlled the painting of statues. The problem which in our day preoccupies the historians of antique art is mainly historical. What is the nature of the evolution through which polychromy has passed from the beginning of Greek art to the masterpieces produced

[1] Translated from Revue des Deux Mondes, vol. 127, February 15, 1895.

by such great masters as Scopas and Praxiteles? Can we possibly mark all the steps and landmarks, can we determine for each period what were the rules that governed the painters of statues? The most conclusive answer would certainly be a systematic statement of the facts that have been observed. Without claiming such accuracy here, I shall endeavor to characterize, with the assistance of the most important testimony, the principal phases through which Greek polychromy has passed.[1]

I.

In order to explain the use of polychromy in Greece, frequent reference is made to the influence of the climate, to the peculiarity of an intense light which often blinds the sight, and which on hot summer days, drowns, as it were, the shapes of things and their outlines. At hours when the heat is less fierce, this diffusion of light seems to have no other end than to caress colored forms, and this "all joyous sky," to quote a Greek poet, would look almost offended by the cold and dim "tones," with which we must be content in our climate. This argument has not lost its value because it has so often been invoked, and we are still quite ready to acknowledge that a privileged sky has evoked in the Greeks, as in the Egyptians and the Asiatics, an instinct and a necessity for color. But polychromy exists already in primitive Hellas, long before art was sufficiently advanced to understand its laws and to analyze its harmonies. It has the same origin as the plastic art, and a very modest beginning it is. At a time when statuary was represented, all in all, by a few wooden statues, which wandering image carvers squared with the ax and shaped with the saw and the gauge, painting was the never-failing complement of the work of these implements: it serves to conceal its shortcomings and gives to the work a semblance of life. Ancient writings allude more than once to old idols, painted or gilt, and we know that when religious traditions require it, even in the classic period such wooden images were produced and adorned with colors. Thus at Delos, in the third century, a statue of this kind was ordered to be made every year, to be worshipped on the great festive day of Dionysius: it passed through the hands of the

[1]Quatremère de Quiney was the first to undertake a systematic study of antique polychromy in the Jupiter Olympien (Paris, 1815). Much has been written on this question, and as for ancient works we must refer the reader to the list of writings given by Mr. Sittl, Archæologie der Kunst, page 411, in the Handbuch der klassischen Altertums-Wissenschaft of Iwan von Müller, Munich, 1895. We shall quote here only a few of the more recent comprehensive publications: Georg Treu, Sollen wir unsere Statuen bemalen? Berlin, 1884. Blümer, Technologie und Terminologie der Gewerbe und Künste bei Griechen und Römern, III, p. 200 and following: Th. Alt, Die Grenzen der Kunst und die Buntfarbigkeit der Antike, Berlin, 1886. Geskel Saloman, Ueber vielfarbige und weisse Marmorskulptur. Stockholm, 1891. Th. Ballorn, Die Polychromie in der griech. Plastik. Zeitschrift für bildende Kunst de Lützow, 1893. E. Robinson, Did the Greeks paint their sculptures? The Century, New York, 1891–92. Articles on special subjects will be mentioned hereafter.

painter, who received the same compensation as the sculptor.[1] What such daubing may have been toward the eighth century before our era, we can at least imagine easily enough, when we look at the primitive terra-cotta figures, and the popular images which have come down to us like so many cheap reductions of idol statues. This violent daubing, these red patches that stain the cheekbones, give us an impression of what this barbarous coloring may have been: and the impression would no doubt be very much the same if the impossible should happen, and we should dig up some wooden statue. To look for laws which define the use of polychromy in works that no longer exist would be building castles in the air. But what these ancient records teach us is to make allowance for the religious sentiment that dwells in these naive æsthetics which associate color with shape. According to old Greek ideas, the statue of the god is really animated by a divine power: these idols are living beings. Statues are believed to move their hands, perspire drops of blood, and impart to such as touch them a supernatural strength. They change miraculously their habitation—a statue of Apollo goes and defends the walls of Corcyra. They are adorned with jewels and with clothes: they are perfumed like other beings of flesh and blood. As a matter of course, the image of the god must have every appearance of life, and art must employ all its resources, giving them both shape and color. This coloring will at first be a crude daubing, but it will please the god and the *Χόανον* under its layer of vermillion or of "lees of wine", and will fill the devout worshippers with the same awe with which they were later on inspired by the Athene of Phidias, resplendent at the Parthenon in all the brilliancy and glory of her rich, metallic polychromy.

We will now leave those obscure days and turn our attention to others still very distant, but such as have left us unmistakable evidence—we mean monuments. During the seventh century before our era, Greek sculpture began to employ a material that is more durable than wood. Certain privileged schools already used marble that came from Paros or Naxos, but in continental Greece the sculptors were still content with softer stone—first a friable limestone, full of shells and abounding in cavities; later, as their tools improved and they were better able to choose their material, a stone of closer grain and more resistance. The study which we are able in our day to devote to these primitive sculptures extends already over a considerable number of monuments. From the metopes of Sélinonte to the recently discovered sculptures at Delphi, belonging to the treasure of the Sycionians, a large number of such examples might be enumerated. The tufa pediments, sculptured in bas-relief or in high-relief, which were found from 1882 to 1888 in the excavations of the Acropolis at Athens, occupy a place of honor in this remarkable series of works.[2]

[1] Bulletin de correspondance hellénique, 1890, page 799. Article by Homolle.

[2] They have been the subject of a very comprehensive essay by Lechat, Les sculptures en tuf de l'Acropole d'Athènes, Revue archéologique, 1891.

If wooden statuary already requires the use of colors, sculptures of soft stone exact it likewise as an indispensable complement. The sculptor who uses this friable material that yields so readily to the chisel can not reproduce all the details of the shapes that make up his model. And even if he wished it, even if he had the talent that is needed, he would not be able to do it because of the imperfect tools and the quality of the stone. It has been very justly asserted that the monuments themselves attest the inefficiency of the tools that these primitive artists used; it was always the saw and the gauge with which these image makers shaped their wooden idols. A sculptor of the sixth century might have carved a stone so as to produce a statue or a pediment, but would he have considered his work completed when he had summarily modeled large, level surfaces and hollowed out the limestone with his gauge so as to shape the curls of the head or the folds of the drapery? His eye will be shocked by the defects in the stone, by the rough and uneven aspect it presents. There will be a call for painting that is here also to play its part, to conceal the imperfections of the material, to beautify the work, and to give to the statue its final, definite aspect. In such cases, polychromy ought to be as complete as possible, and it is thus, indeed, that the monuments show it to us, especially the pediments of the Acropolis, in which color, freely diffused over all the sculptured parts, covers them with simple, quiet tints liberally distributed. Thus we obtain a well-established law for primitive Greek art, whether the work be a statue or a bas-relief—sculpture in soft stone requires complete coloring.

What is, on the other hand, the representative value, so to call it, of such polychromy? Does it aim at reproducing the reality of the colors, to give within the limits of its resources the semblance of life? As far as statuary, properly so called, is concerned, we hardly possess anything more than mere fragments—some heads and parts of draped statues.[1] They show us some reds and some blues applied to the garments. At times the flesh is painted red. As we meet with the same colors in monumental sculptures, we may take it for granted that polychromy follows the same laws in both cases and preserves the same character. Now it is, beyond all doubt, purely conventional. Examine with a view to this point the most remarkable of the pediments carved in soft stone that has been found on the Acropolis of Athens, that which contains, among other figures, the strange shape of Typhon, consisting of three busts of men, each of them provided with a serpent's tail.[2] The prevailing colors are red and blue. They alternate in long stripes, which cover the bodies of the serpents, in the ornamentation of the unfolded wing belonging to one of the busts. The absolute indifference of the painter with regard to truthfulness, or even probability, is clearly enough shown by the eccentric coloring of the heads.

[1] Holleaux, Bulletin de correspondance hellénique, X, Pl. VII.

[2] Revue archéologique, 1891, Pls. XIII–XIV.

Who does not nowadays know the head of one of the triple busts of Typhon, or "Blue Beard," to give its popular name?[1] With his blue hair and beard, his big eyes and their yellow eyeballs, his green iris hollowed out into a black hole to represent the pupil, this head would seem to have been a challenge to good sense if we did not know that the painter had purposely remained within the bounds of conventional rules. In like manner we see, with no very great astonishment, among the fragments of another pediment, two lions with pale pink bodies tearing with their claws the body of a blue bull, on which long red lines represent streams of blood. Blue and red are evidently the favorite colors of architectural polychromy, and their choice is easily explained. The painter who colored these pediments desired, first of all, to bring them in harmony with the architecture. He therefore employed the same warm and vibrating tones which enliven the architraves and the ogees.

Painting all over, because the material requires it, conventional painting, because it had to conform to that used in architecture—such is the nature of polychromy in monumental sculpture toward the middle of the sixth century before our era. When this rule is applied to bas-reliefs it leads to consequences which are original enough to be pointed out here. In fact, the polychromy of bas-reliefs, looked at in the light of what in the language of studios is known as the relation of values, may be considered under two aspects, either the figures stand out vigorously from a light background or they are disappearing in the clear from a dark background. The primitive artist who worked in soft stone naturally preferred the former method. One of the pediments of the Acropolis of Athens, that in which Hercules fights the hydra of Lernea, shows us a kind of silhouette reproduction of figures painted all over on a ground which preserves the natural color of the stone.[2] The combined effect recalls quite forcibly that produced by vases with black figures, on which the various personages contrast with a ground of clay. This analogy with the painting of vases has seemed more striking since we have become acquainted with the tufa metopes of the treasure of the Sicyonians discovered at Delphi. Not only has the background on these metopes never been touched by the brush of the painter, but by the side of personages, colored with bister or an orange-red, inscriptions in black letters indicate their names.[3] We could not imagine a more perfect resemblance to the decoration of a Corinthian vase. Such facts lead us to think that the polychromy of the bas-reliefs has pretty closely followed the traditions of painting. Thus, it also feels effects of the

[1] It has been reproduced with its colors in a large lithographic plate in Antike Denkmaeler herausgegeben von deutschen archaeologischen Institut, I, 1889, pl. XXX. Compare plate II of my Histoire de la sculpture grecque, Vol. I.

[2] See P. I. Meyer, Athenische Mittheilungen, X, pages 237–322, and the comparison with the painting of vases pointed out by Mr. Brownson, American Journal of Archæology, VIII, pages 28–41.

[3] See the article by Mr. Homolle, Gazette des Beaux Arts, December 1, 1891.

revolution which about 520 or 530 modified the technics of painted vases. Under the influence of the progress made by painting, and carried away by an impulse due perhaps to the innovations of Cimon of Cléones,[1] the ceramists abandoned their old methods. In the place of those black silhouettes, set off by a kind of slip or white paste, but rather sad of aspect, they now prefer clear figures enclosed in a brilliant black ring; in other words, they reverse the relation of values. Will the painters of bas-reliefs remain faithful to superannuated customs? We know they did not. Here, for instance, is a well-known monument, contemporary with the first Attic vases with red figures—we mean the Stela of Véladinéza—in which an Athenian, Aristion, is represented in war costume. The ground has preserved a somber tint that sets off the bright effects of the flesh parts and the nets of the hair, which are skillfully managed so as to isolate certain details, like the shoulder piece of the armor.[2] One of the most important discoveries which we owe to the excavations made by the French School at Delphi furnishes an additional argument. In the magnificent frieze of the Treasure of the Siphnians the ground had been painted blue, and if the armor and the clothes have kept some traces of color, no such are seen on the uncovered parts. The artist had, moreover, taken care to prevent the colors of the accessory parts from being confounded with those of the ground. A warrior may have a blue helmet on his head, but this part of his armor is very cunningly surrounded by a red edging, and thus the eye perceives the outlines very accurately. The painting of bas-reliefs is evidently inclining toward a new system, which will cause sustained efforts to be maintained, and in order to continue a comparison borrowed from ceramic painting, a polychromatic painting will, as far as the total effect is concerned, recall the effect of a vase on which red figures stand out from a dark ground.

The stela of Véladinéza and the frieze of the Siphnians are marble sculptures. The evolution of which we are speaking coincides, as we have shown, with the employment of a material finer than soft stone, and which, toward the middle of the sixth century, almost everywhere took the place of the tufa, so dear to old sculptors. With the use of marble for sculptures, polychromy also entered upon a new phase.

II.

Marble is for us a rare and costly material; there is, as it were, a feeling of economy in our regard for it, and this is no doubt one of the reasons why the idea of polychromy was for a time looked upon as a

[1] As to this question we refer our readers to the work of Mr. Paul Girard, La Peinture Antique, page 141.

[2] This bas-relief has been reproduced in all its colors in the work entitled Die Attischen Grabreliefs, published by the Academy of Sciences at Vienna, under the direction of Mr. Conze. See Pl. II. Concerning the relations between the polychromy of Attic stelæ and painting, interesting observations will be found in an article by Mr. Loeschcke, Athenische Mittheilungen, IV, page 26 and ff.

kind of sacrilege. To apply an artificial coloring to beautiful Greek marble, with its pure grain, seemed to be almost a profanation. No doubt the Greeks knew its full value. The marble of Paros was an article of exportation, and, notwithstanding the richness of their own Pentelicon, the Athenians bought it and paid a good price for it. But marble was still only "white stone" for them; in other words, a stone of greater beauty and greater consistency than limestone, offering in these very qualities greater advantages to the architect and the sculptor. The use of this new material did not at once cause old habits to be abandoned: polychromy does not disappear; it is only somewhat changed. A safe instinct warns sculptors that this close and highly polished grain, this warm transparency, this gentle glow, must all contribute to the beauty of artistic work, and that the problem which they have to solve is, how to conciliate the exigencies of the material with those of color. This problem archaic masters are bent upon solving, and they do it with as much good taste as decisiveness.

We are nowadays perfectly well informed as to the painting of archaic marble statues, and, to speak only of the most widely known discoveries, the excavations on the Acropolis of Athens have revealed it to us in unexpected accuracy. The statues of women, gathered together in the Museum of the Acropolis, are well known. These marble figures, which revive for us the contemporaries of the Pisistratides, have often been described; their somewhat stiff attitudes have been commented upon with some self-complacency; their gestures, apparently regulated by a kind of coquettishness, have been studied, as well as their festive costumes, with their long, regular folds, and the cunning arrangement of the hair.[1] The minute carefulness of the execution warns us that the art of working in marble has now reached its highest technical perfection, and that any progress to be made hereafter can only be a progress in style. The artists who have carved these statues, between 520 and 480, are sure of their chisels, as the painters who decorate them are sure of their principles. Polychromy now follows established rules and no longer proceeds by experiments. We may therefore choose an example which will save us long descriptions, and examine, from among the statues of the Acropolis, one of those that has preserved most valuable traces of having been painted.[2] Let us look first at the head, with its hair curiously wrought in detail by the chisel; curls are rising stage upon stage in front, tresses are flowing down upon the breast, a mass of hair is spread out over the shoulders in one large sheet, as it were, marked with regular undulations. In

[1] The most complete account of this subject will be found in Mr. Lechat's articles in the Bulletin de correspondance hellénique 1890, pages 301–362, 552–586. The same author has very closely examined the polychromy of statues, and I only sum up here his conclusions.

[2] This is the statue which is represented on Pl. III of the Musées d'Athènes. A colored plate, published in the Antike Denkmäler I, Pl. XXXIX, gives the colors of the costumes.

order to perfect the sculptor's work, but one plain tint will be required, and this tint is borrowed from one of the conventional colors, the reddish brown, which is going to be constantly used, even at a much later date, by the painters of statues. In contrast with this quiet and solid coloring, the flesh of the face is left as it is, and the tone of the marble reappears, together with its transparency. On the other hand, the lips are red; the eyebrows and lids are marked with a black line; the pupil is black and surrounded by a red circle, to represent the iris. Polychromy, heretofore total and complete, is now therefore limited to certain parts—to the same parts which in living nature contrast by their natural coloring with the color of the skin. If we next examine the costume, we notice here the same recoiling of solid colors which makes room for the whiteness of the marble. Here, again, color takes refuge in the decorations, large stripes embroidered with fretwork and winding lines which adorn the front of the chiton or the borders of the peplos; in the laces which border the neck of the chemisette, in the flowery shapes, the foliage, and the crosses that form, as it were, a scattering of seed on the drapery. Everywhere else the tone of the marble recalls the warm whiteness of woolen or linen stuffs, and if the painter does not altogether forego the solid colors he reserves them for more limited spaces, like the top of the chemisette, which shows from under the drapery of the peplos. The colorist employs this polychromy, that has now become but partial, with great caution. He takes pains to engrave with a burin a kind of sketch of the ornamentation, and this slight hint guides his brush so as to follow the complicated design of the fretwork and winding outlines. This is, besides, a process by no means peculiar to Athenians. The seated statue of Charès in the British Museum, the statue of the Victory of Archermos in the Central Museum at Athens, all preserve alike traces of this engraved sketch which bears witness to the use of painting, even at a time when every vestige of color has disappeared.

Thus, we find the statue painted according to the rules of archaic polychromy. Dull, solid colors, without transparency, stand out from the marble which forms the ground. The tones that prevail in this scale of colors, limited as it is, are always the same as those used in monumental polychromy—that is to say, red and blue, at one place freely spread over, as over the hair or the chiton, elsewhere knowingly combined so as to form the attractive ornamentation of stripes and seed-like adornments. A few fine black lines mark the details of the eyes and the arch of the eyebrows; here and there, on the pendants from the ears and upon the frontlet that crowns the coiffure, some gilding adds a metallic sheen; the painter's brush has finished its work.

Has a statue thus painted assumed the appearance of life? Is it a realistic sentiment which has suggested the choice of colors and the manner of applying them? By no means! The whole ambition of the painter has been his desire to remain within strict conventionalities,

to improve the sculptor's work by the charm of colors, and to perform an artist's work without any effort to mislead the eye by a willful imitation of the reality. Hence, the exquisite precautions he takes to prevent any vulgar accident from tarnishing the freshness of this delicate coloring! Look at this metal spike fastened to the top of the head. This is to support the crescent, called a meniscus, made of wood or of metal, which protects the statue against the offences committed by birds, and to secure it against the defacements with which it is constantly threatened by those indiscreet guests of the Acropolis.

Does this coloring of the statue complete its toilet? It has been justly remarked that the contrast between the painted parts and the natural tint of the marble would be too painful to the eye unless a kind of treatment with the hand—a patinage—should reestablish the proper harmony by softening this rather crude whiteness. Archaic marbles have preserved no trace of such a treatment, but this fact is easily explained. But at a later date we meet with several examples, and the written texts make frequent allusions to it. Nothing prevents our believing that the artists of the sixth century had already comprehended the necessity of a proceeding which, as we shall see further on, plays a very important part in the classic period.

III.

The adversaries of polychromy may look upon the limitation of painting to certain parts of archaic statues as a symptom of approaching decline. It looks to them somewhat like an ancient tradition which still survives, but is doomed to disappear. Or is it rather a shrinking back—a movement such as that which was observed in Italian sculpture toward the beginning of the sixteenth century? And when, afterwards, the great masters of marble statuary, with Phidias and his successors, shall try to find in their modelings the most delicate tints, when they shall give to drapery a matchless elegance and nobility, will they not then repudiate superannuated proceedings employed by primitive image makers in order to hide the shortcomings of their chisel?

Here we come upon a most earnestly controverted question. As far as the brilliant periods of the fifth and fourth centuries are concerned, the facts are more widely scattered, the pieces of evidence do not succeed each other with absolute regularity, as they do in that matchless totality of the sculptures on the Acropolis. Still, by combining all the information we find here and there, they present a cohesion which is by no means factitious, and gradually we are convinced. We come readily to the conclusion that polychromy has survived the primitive archaism for many centuries.

Monumental sculpture and bas-reliefs present to us certain landmarks; they follow each other during a long period, extending from 470 to about the end of the fourth century. Traces of color have been found upon the metopes of the temple of Zeus at Olympia, and on the drapery

of the colossal Apollo, that once stood in the center of the western pediment. If the investigations made at the Parthenon have led only to uncertain results, the frieze of the temple of Theseus, of a somewhat later date than that of the Panathenes, has preserved traces of coloring. When Mr. Newton, in 1856, on the place where the Mausoleum of Halicarnassus once stood, conducted his memorable excavations, he could discover on the grand frieze upon the costumes of the colossal statues which crown the edifice, traces of color, which were then very apparent, but are now almost extinct.[1] Polychromy, however, remains still very visible on the marble lions, which no doubt came from the same monument. We can easily restore the brownish-red tone of the body, and the bright red that has been put on the lips and the tongue that hangs out of the half-open jaws. It will thus be seen that polychromy still exists on monumental sculptures in the middle of the fourth century, at a time when Scopas and his followers were decorating the sumptuous tomb of the Carian king, Mausolus; the harmony has not yet been interrupted that reigned between architecture, brightened by elegant polychromy, and the sculpture which forms, as it were, one body with the edifice.

Is the inquiry to be carried any further? We shall look at isolated, independent bas-reliefs, that escape for that very reason from the exigencies of monumental polychromy. In this aspect funeral stelæ can give us curious information. In looking over the collection of Attic funeral bas-reliefs,[2] published by the Academy of Sciences in Vienna, we gain the conviction that these stelæ, now mostly without any color, still had received their final touch at the hands of the painter.[3] The brush completed the decoration of the pediment and of the pinnacles which crowned the stela and indicated the details which the sculptor had neglected, like the accessories of the toilet, the staff on which the personages, clad in their cloaks, were resting, and would look as if they were suspended in the air if the painter had not come to the rescue and restored the equilibrium. One of the most beautiful of the stelæ of the Museum at Athens, that of Prokleides, has preserved traces of a red background, on which the blue drapery of a seated personage stands out very clearly. Another stela belonging to Aristonautes looks now as if it had no coloring, but at the time when it was discovered it still presented the rich decorations of its moldings, its cornice, and its tympanum. "The warrior's shield," wrote Mr. Lenormant, "was painted red, and in the background of the relief there still appeared traces of the blue tint with which it had originally been covered again. All this has vanished under the influence of rain and

[1] C. T. Newton. Discoveries at Halicarnassus, Cnidus, and Branchidæ, I, pages 101, 222, and ff.

[2] Die Attischen Grabreliefs.

[3] The mutual assistance which painting and sculpture render each other in Greek bas-reliefs is very interestingly discussed by Mr. Conze in the Sitzungs-Berichte der Berliner Akademie, 1882.

exposure to the air." We know, moreover, quite a numerous series of stelæ in which the bas-relief is replaced by painting directly applied to the marble,[1] and in monuments of careless workmanship as in cheap stelæ, a sketch is often found slightly engraved and intended to guide the painter. We must, therefore, take it for granted that a Greek necropolis, like that of the outside ceramic works at Athens, owed to the polychromy of the monuments a much less stern aspect than that of our cemeteries; painted tombs, stelæ adorned with colored reliefs formed here long lines in picturesque perspective; the wanderer who stopped before one of these beautiful bas-reliefs enjoyed here the charm of form united to that of color, and if we wish to evoke the vision of an Attic stela with its delicate polychromy, we should recall the painted stuccoes of the Renaissance, and forget the stone or marble reliefs which adorn the most luxurious of modern burial places.

The most striking and the most conclusive example of polychromy applied to bas-reliefs happens to be a funeral monument. Before the end of the fourth century a Greek sculptor, a contemporary of Alexander, created that magnificent sarcophagus which Hamdy-Bey was so fortunate as to discover in the necropolis of Sidon. This is the "Sarcophagus of Alexander," now the most precious work in the Museum of the Tchinily-Kiosk at Constantinople.[2]

We are not called upon here to describe in detail the bas-reliefs which so liberally cover the four sides of the huge coffin: an episode of a hunt for panthers, a lion hunt, in which a Persian and a Greek, no doubt Alexander, are the principal personages, a furious skirmish of cavalry between Macedonian and Persian soldiers, a densely crowded composition, in which we meet again all the rush and the fury of the battle scenes sculptured by contemporaries of Scopas, at Halicarnassus. In spite of the interest we feel in these bas-reliefs, which are very justly deemed to represent to us the beginning of historic sculpture in Greek art, we can not stop for anything but the object of this essay. Now, far from betraying a decline of polychromy, the "Sarcophagus of Alexander" shows it to us more flourishing than ever; it has actually gained new resources. Instead of the three or four tints which the painters of the sixth century employed, the decorator now commands a very rich palette, which includes violet, purple, blue, yellow, carmine red, reddish brown, and perhaps dark-brown bister. Instead of timidly limiting the field of painting, he lavishes solid colors, spreads them in abundance over the tunics and fluttering cloaks, and disposes of this greatly varied gamut with singular facility. "The man who illuminated our sarcophagus," writes Mr. Theodor Reinach, "is a genuine colorist; he not only imitates with minute accuracy the complicated

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[1] Milchöfer, Gemalte Grabstelen, Athenische Mittheilungen, V, 1880.

[2] It has been reproduced in very beautiful heliogravures with a lithograpic plate in the folio Atlas published by Hamdy-Bey and Theodor Reinach: Une nécropole royale à Sidon. Paris, Leroux, 1892.

patterns of Oriental stuffs—the tunics and their solid ground, purple, blue, or red, embroidered with little squares or ornamented with an insertion of a different color, the facing contrasting with the sleeves, the sleeves with the mantles, the trousers striped, dotted, or dappled sometimes in three shades, the saddlecloths with their brilliant braids and their figured embroideries—but more than that, he excels in the delicate art to please the eye by very sharp contrasts, and yet to harmonize the colors."[1] Nor is polychromy here limited to the clothes and their accessories. The heads, with their brownish-red hair, the eyes, in which the iris is always carefully indicated as blue or brown, have a marked lifelike expression. The head of Alexander in the scene from the lion hunt is worth examining as proving our assertion; his eye, fixed upon the animal which is biting the chest of one of his horses, has all the intensity, all the energy which a painter could have wished to express in a painting. Take, moreover, this essential fact which is productive of weighty consequences. The difficult question of coloring uncovered parts is made quite clear by positive evidence. The bare parts were covered up "with a kind of light and transparent rubbing in of uniform density, light or dark yellow, according as the subject was a Greek or a barbarian, without any effort to reproduce the varying aspect of flesh and blood by a variety of shades. These glazings are so different from the even, opaque, and consistent tints which are applied to parts of the drapery, and time has so successfully gnawed away the fluid veil that at first sight one might imagine nothing was there but the natural marble, gilt by the years." Thus, about the year 320, far from having lost ground, polychromy had rather improved and progressed, and if new evidence were needed to prove this, abundance of it would be found in the other monuments discovered at Sidon; the painted friezes of the sarcophagus of the female mourners would furnish an additional argument. All these facts combined lead us to the conclusion that there were laws, or, if we prefer it, established customs, that regulated polychromy for bas-reliefs. In the first place, the decorators did not abandon opaque colors; on the contrary, they used them freely. As to bare parts, they solved the problem as above mentioned; they employ for them a colored glazing that is transparent and allows the grain of the marble to show, while it tempers the whiteness which they thought too glaring. Finally, we do not notice at this period, more than at any more remote date, any doubtful tints, nor any modeling by color. It is the prominent parts of the bas-relief alone which give to the lights their effect and to the shadows their intensity. The painter has nothing to do with modeling; he only colors with solid tints the sculptured surfaces which have in themselves their own play of lights and shadows.

Relying upon such very precise indications, we may with tolerable safety turn to the most important question—the painting of statues.

[1] The Sidon sarcophagi in the Museum at Constantinople, Gazette des Beaux Arts, 1892.

Here the problem becomes more difficult. We have to deal with isolated works, made for their own purposes and having no connection with architecture. The question mainly concerns plastic creations, which according to our modern ideas require nothing but form in order to give them all their great value and their peculiar accent. It has long been thought that the chisel of Scopas and Praxiteles gave to the marble sufficient life to convey by the modeling alone the passionate outbursts of the "Maenade with the Kid," or the perfect beauty of the "Cnidian." And is it not really a barbarous idea to attempt concealing, even under the slightest touch of coloring, the exquisite delicacy of the marble as it has been shaped by the chisel of great Greek masters?

We would not dare assert that the polychromy of statues has been an absolute, inflexible rule, and that it rigorously bound all artists alike. But if the facts are conclusive, we must needs accept it, if not as a law, at least as a custom, to which the taste of antiquity submitted gracefully. Now, we find at the very outset in the written evidence many reasons to overcome our doubts. The principal texts which in any way allude to the painting of statues have long since been collected and commented upon, and we ought to bear in mind that they spread over a very long period, from the fourth century before our era to a very advanced date in the times of the Emperors.[1] Greek statuary is in its full splendor when Plato writes as follows: "If we were to paint statues and some one were to come and object that we do not employ the most beautiful colors for the most beautiful parts of the body; that, for instance, we do not paint the eyes vermilion, but black, we should think we had answered the censor very well by saying to him: 'Do not think that we ought to paint eyes so beautifully that they cease to be eyes; and what I say of this part of the body must be understood of the others likewise.'" Pliny has preserved a saying attributed to Praxiteles and evidently taken from Greek sources. When the great artist was asked which of his marble statues he valued most highly, he replied: "Those which have been in the hands of the painter Nicias!" And Pliny adds: "So great was the importance which he attached to the work (circumlitio) of Nicias!" This cooperation of painter and sculptor ought not to surprise us; we meet with its equivalent in the days of the Italian renaissance. Thus Lorenzo di Credi and Cosimo Roselli painted the sculptures of Benedetto da Majano,[2] and in the studio of the painter Neri-Bicci they were coloring "plaster or marble madonnas, works of good masters."[3] Let us go deeper in this line of evidence. Inscriptions found at Delos give us a detailed account of the

[1] See especially Christian Walz: Ueber die Polychromie du antiken Skulptur. Tûbingen, 1853, and Blümmer: Technologie und Terminologie der Gewerbe und Künste, III, page 120 and ff.

[2] Müntz: Histoire de l'art pendant la Renaissance, II, page 462.

[3] Courajod: La polychromie dans la statuaire du moyen âge et de la renaissance. Extract des Mémoires de la Société des Antiquaires de France page 65.

payments and the inventories drawn up by the administrators of the temples of Delos. Under the date of 246, mention is made of gold leaf bought for the gilding of a quiver; this is a marble quiver belonging to a statue of Artemis. Elsewhere we find a salary spoken of that was paid to a painter for coloring in encaustics a statue of Aphrodite, and for the finishing touches (*Κόσμησις*) given to another statue of the same goddess.[1] This is an industry the tradition of which is never entirely lost in Greece. After the Roman conquest the Greeks kept the secret and came and practiced it in Italy. A funeral inscription found in Rome introduces us to a Greek sculptor who is otherwise unknown, but who practices the profession of "manufacturer of statues and painter in encaustics."[2] Sometimes the duty of coloring the marbles is left to female hands, as we learn from a Pompeiian fresco, where a woman painter's studio is shown; we see her, brush in hand, busily coloring a statue of Priapus, and consulting a painted sketch that is placed before her.[3] In the second century of our era the best connoisseurs in matters of art look upon polychromy as the indispensable complement of sculpture. We all know the dialogue of the Portraits, where Lucian introduces two overrefined amateurs, Lykinos and Polystratos. In order to realize a type of perfect beauty, the two men borrow from the most celebrated Greek statues all the features of their description: from the Cnidian of Praxiteles her hair and her brow; from the Aphrodite of the gardens by Alcamenes, her round and tapering fingers; from the Lemnian woman by Phidias the outlines of her cheeks and the oval of her face. But that is not all. Polystratos calls for a new element of beauty. "What is it? It is by no means the least interesting, my dear friend, unless the tint that is peculiar to every part appears to you of no importance in point of beauty - - - our work runs great risk to sin on the essential point." And the two great talkers divide out among the most illustrious painters of Greek antiquity the duty of applying such an ideal polychromy. We understand, of course, how Latin writers make likewise very pointed allusions to the painting of statues, how a Roman poet, the author of an epigram on a marble Daphne, should admire both the skill of the sculptor and the skill of the painter,[4] and how another, a contemporary of Augustus, should promise Venus that he will dedicate to her a marble Amor with variegated wings and a painted quiver:

> Marmoreusque tibi, dea, versicoloribus alis
> In morem picta stabit Amor pharetra.[5]

Every mind that is free from prejudice must needs be struck by this unbroken continuity in the evidence. Even if there were no other

[1] Homolle: Bulletin de correspondance hellénique, 1890, page 499.

[2] Loewy: Inschriften Griechischer Bildhauer, No. 551.

[3] Museo Borbonico, VII, 3. Helbig, Wandgemälde der Städte Campaniens, No. 1443. Paul Girard, La peinture antique, page 260.

[4] Anthologie latine, I, page 223, ed. H. Meyer.

[5] In the collection of verses attributed to Virgil. Catalecta, VI.

proof, it must be admitted that the custom of painting statues was evidently not a passing fashion, and that it survived even the Roman conquest. But the written texts have their commentary in the monuments. A complete examination would amount to a catalogue of all the works on which traces of painting have been discovered, and this simple statement of facts would be equivalent to a conviction. But we can not think of undertaking such a minute investigation. We shall be content to quote some examples in order to put down some landmarks on this long road with distant perspectives of which a rapid survey of the manuscripts has given us a glimpse at least.

Pliny's anecdote about the cooperation of Praxiteles and Nicias has nothing that is suspicious about it; on the contrary, the discovery of the only original statue by this great Athenian master which we possess, the Hermes of Olympia, invites us to believe that it is true. The reddish brown, traces of which are found on his hair and on the sandals, bears witness that the painter's brush has put the final touch to the sculptor's work. The marbles which date from the Hellenistic epoch furnish more than one analogous example. An Apollo in the Museum at Constantinople, found at Cymae, bears on his shoulders some red drapery; he wears ornamental shoes, on which traces of red, blue, and ocher are visible. We must especially mention a statuette of Æsculapius in Paros marble, found on the Island of Cos and bought, in 1892, for the Dresden Museum.[1] It presents the curious peculiarity of having not only been painted, but actually painted over again. The primitive color of the cloak had been a rather light brick red. At a later date, perhaps upon the occasion of a revision of all the offerings exposed in the sanctuary of Æsculapius, the primitive painting has been revised, and a new coloring given to the cloak. This time a rose tint was chosen. It has often been asserted that the Greek terra cottas give us a fairly correct idea of the painting of statues, and that especially the small Tanagra figures, with their delicate coloring, their flesh clothed in a very pale tint, their draperies in which soft and very much weakened colors combine, a delicate pink, blue, or violet, and their hair, painted reddish brown, might present to us, in miniature, the image of a polychromatic statue. The process of making them renders this analogy very striking indeed. Before proceeding to the coloring of the little figure, the manufacturer plunges it into a bath of whitewash and white lead. When it comes forth from this, immaculate under its slight layer of white, which is to be the ground work for the painting, it presents very nearly the appearance of a small marble statue, ready to receive its final dressing at the hand of the painter. And will not the artist who is to color it be under the influence of the usual custom in coloring large statues? The recent excavations carried on by the French School of Athens, at Delos, furnish us with curious information on that question. Amid the ruins of a

[1] Arch. Anzeiger, Jahrbuch des arch. Instituts, VII, 1892, page 159.

house at Delos, Mr. Couve has discovered a beautiful statue of a draped woman, equal in point of elegance to the most coquettish of the little Tanagra figures. The hair, artistically arranged in bandeaux, displays a brownish red tint; this is exactly the type of the dressing of the hair and of its color which we find in terra-cotta statuettes. It is, moreover, the conventional color chosen by the manufacturers of such ware to reproduce, as nearly as can be, that brilliant golden tinge which a Greek traveler admires so greatly in the hair of Theban women.

Toward the middle of the second century before our era, Greek art undergoes a kind of evolution, which is often called a renaissance. This is the time when a school of new classics, reacting against the tendencies of Alexandrianism, resolutely returns to the traditions of the two great centuries, when able sculptors, like Apollonius, Glycon, Cleomenes, put their names to a torso in the Vatican, a Hercules Farnese, the so-called Germanicus in the Louvre, and adopt as their models the works of the fifth and fourth centuries. Greek sculptors emigrate and go to Italy. To satisfy the demands of their Roman patrons, they multiply copies of celebrated statues. The villas, the palaces of rich Romans, are soon full of marbles carved by skillful artists, whose works of art mostly furnished the models after being carried away out of Greece. Did polychromy survive these new conditions? Will it become acclimatized under the Italian sky? It would be strange if the taste for archæologic amateurship and the erudite curiosity which were aroused in Rome should not have become a guaranty for its vitality. We do not see that it suddenly gives way to monochromatic sculpture. Far from it. Instead of proscribing the union between sculpture and painting, the Italian taste eagerly accepts it. It is the time of the Emperors that produced those colored marble statues of green basalt, porphyry, antique red (rosso antico), which had heretofore been peculiar to Egyptian art. The employment of such marbles, imported from Numidia or Egypt, is favorable to the development of a very special kind of polychromy that might be called natural polychromy. It produces those statues of variegated marble which cause our modern taste to hesitate, and which, if they fail to secure our admiration, at least excite our curiosity.

How could painting by the side of a statuary art so daringly many-colored fail to maintain its rights, protected as they were by old traditions and by the prestige of Hellenic art? It maintains them so well that it is to Græco-Roman sculpture we owe very many and very conclusive specimens of colored statues. In 1885, there was found in Rome, on the ground of Sallust's garden, a head of Athene, which evidently is a copy of the Parthenos.[1] The painter has endeavored to keep as close to his model as he can and give to his work the appearance of a chryselephantine statue. While the flesh, carefully polished, preserves the clear tint of the marble, the yellow color of the helmet represents the

[1] Antike Denkmäler, 1886, I, Pl. III.

effect of gold. Hair and eyebrows red; the iris dark brown, suggests the idea that the painter, unable to bring out all the shades of the various kinds of gold and precious stones, has employed a conventional coloring. Many will say this is a copy of a chryselephantine work; in other words, this is an exceptional case. Let us, therefore, examine other works, copies, which reveal to us most readily the originals in marble. In the British Museum there is a precious head of marble, carefully protected by a glass case against atmospheric influences. It was found in Rome in 1884, and no doubt belongs to a statue which once adorned the gardens of the Esquiline, and the general style, the shape of the coiffure, betray a replica of a Greek original, dating from the fourth century.[1] If we consider the light yellow shade of the hair, the rosy flesh tint that still covers the brow, the cheeks, and the neck, the black pupils of the eyes, we can not hesitate to feel that the copyist has respected the polychromy of his model. Has he transferred it with all desirable delicacy? That is another question, but his testimony is too valuable for us to blame the painter for having shown himself a rather poor imitator of Nicias. With the London marble we must again compare a head of a goddess, bought in 1888 by the Dresden Museum, whose blonde hair is confined by a pink-colored headband, while the face still shows evident traces of having been treated with wax.[2] Add to this a curious statuette of Aphrodite, discovered in Pompeii in 1873, very coquettish under her orange-colored cloak with its grayish-blue lining and white border, and accompanied by a little archaic-looking figure in a yellow peplos and green chiton,[3] and you will have a proof that the polychromy of marble is still very much to the taste of Romans in the first century of our era. No one will be astonished to find in Pompeiian frescoes reproductions of painted statues with a well-sustained peculiar tint for the fleshy parts. Is this nothing more than a concession made to the curiosity of amateurs? Does polychromy remain a kind of reward for amateurs, and is it excluded from official statuary, which multiplies the statues of emperors and great personages? Here, again, we might have ground for believing the contrary. We shall quote but one very striking example. The statue of Augustus, which was found in Livy's villa, on the Flaminian road, and is now in the Vatican, is well known.[4] The Emperor, in military costume, seems to be addressing his troops. It is an admirable work, belonging to the first years of our era. Now, the fragments of color which are still very

[1] It has been reproduced with all its colors in Pl. I of the Jahrbuch des arch. Instituts, 1889, Vol. IV. The plate is accompanied by a very learned article by Mr. G. Treu, page 18.

[2] It is pointed out by Mr. G. Treu, Arch. Anzeiger, page 83, Jahrbuch des arch. Instituts, 1889.

[3] Dilthey, Arch. Zeitung, 1881, page 131, Pl. VII.

[4] Helbig, Musée d'archéologie classique de Rome. Transl. by Toutain, I, page 5, No. 25.

[5] Annali, 1863, pages 450-452, Monumenti inediti, VI, VII, Pl. LXXXIV, 2.

apparent—a bright-red tunic, a dark-red pallium, armor bordered with yellow fringes and ornamented with chiseled relief, set off with carmine, purple, and blue—all give us the idea of a statue on which the richest polychromy has been lavished. Before we lose the last trace of this persistent custom, we have to go very far down into the times of the Emperors. A statue of Faustine, the wife of Antonine the Pious, who died in 141, shows that the habit of gilding the hair and of embellishing the drapery with color was then still in existence.

IV.

All these facts are sufficient, it seems to us, to prove the essential point; to show how unfounded the prejudice is which for a long time refused to believe that there was any painted statuary in Greece. But they do not yet satisfy our curiosity; we should like to know a great deal more about it. Instead of painfully searching for marbles, scattered about here and there, that have faint traces of half-effaced coloring, we would like to have a clear and complete view of a painted statue in all the freshness of its polychromy, and to know accurately what harmonies a master like Nicias could realize by adding to a marble carved by Praxiteles the charm of colors. We must be resigned; we can only very imperfectly catch a glimpse, as it were, of the full effect of a painted statue. In order to conjure up at least a faint image, we should have to give up mere theories, resort to practical applications, and try to re-create, either by molding or by a copy in marble, the colors, as we restore on paper, with fragments of columns and capitals, the order of a Greek temple. This is not a dream that can not be realized. Similar efforts have been made from time to time. In 1885, the eminent director of the Albertinum in Dresden, Mr. Georg Treu, organized in the Berlin National-Galerie an exhibition of polychromatic statuary, belonging to all countries and all ages, from Egyptian statues in limestone to painted marble busts and friezes in majolica by contemporary artists. By the side of a painted relief in wax by our countryman, Mr. Henry Cros, of busts in wood and in terra cotta or in marble, coming from Italian and Spanish schools, Greek polychromy was represented by moldings, which reproduced the colors of the originals, or by restorations, such as a grand draped statue from Herculaneum, painted in wax by Mr. Ludwig Otto.[1] More recently, investigations carried on by Mr. Georg Treu in antique polychromy, have resulted in Dresden in still other efforts, which deserve most careful attention. Mr. Treu has been kind enough to send me notes on the subject, full of details, and accompanied by photographs of moldings after the antique, colored by Mr. J. E. Sattler; the Satyr leaning on his elbows, in the Capitol, has been restored with all the tints of gold and of ivory of a

[1] Ausstellung farbiger und getönter Bildwerke in der National-Galerie zu Berlin. Berlin, 1885.

chryselephantine statue. The head of the Ludovisi Medusa, with its mass of dark hair and the flesh tint that covers the face, stands out from its blue ground like a painted stucco of the Renaissance. Similar efforts have been made in America. In Boston an archæologist, Mr. Robinson, and a sculptor. Mr. J. Lindon Smith, combined their efforts to restore the polychromy of the Hermes of Praxiteles and the Venus genitrix of the Louvre.[1] It is not for us, at such a distance, to judge of the value of such restorations; at all events, they do this at least, they cause a problem, which is still much studied, to enter into an entirely new phase. Mere theories are now followed by practical experiments and by applications of theories, which may furnish interesting subjects for discussion. In fact, words alone will never express what is so eminently subtle—so very fleeting; we mean depths of color, harmonies of shades, transparencies playing on the ground color of the marble. To do the best we can, we shall at least endeavor to sum up our conclusions; and in order to choose an example that may render them more precise, we will inquire what may have been the polychromy of a statue such as the Hermes of Praxiteles?

In the condition in which it has reached us the statue presents only faint traces of having been painted. If we forget the mutilations and stains which disfigure it, it therefore looks to us as it appeared to the eye after the sculptor had given it the final touch. Now, the very nature of the process seems to point out in advance the field that was left to polychromy. Certain parts are reserved for those simple transparent "rubbings" which the "Sarcophagus of Alexander" has taught us to know, other parts will receive a coloring of greater solidity. The work on the face and on the body, carried on with exquisite, almost caressing delicacy, and reaching the very daintiest shades, is such as to exclude any thought of opaque coloring which would cause this matchless flower of the modeled form to disappear; the brush is bound to respect these fleshy parts which the file of the sculptor has so lovingly polished. On the other hand, the hair is treated with much freedom, without what is sometimes called virtuosity. The drapery thrown upon the trunk of a tree hangs there in broken folds, cross lines which by contrast bring out more forcibly yet the effect of the uncovered parts where the light is playing upon surfaces that melt into each other most harmoniously. Here, therefore, we may look for opaque colors. As for the hair, we need not hesitate. The reddish brown that painters of statues affect so much is again apparent. The draperies of the Hermes and the little Dionysius will, of course, be blue or red, but we may certainly assume, without venturing too far, that in a work of the fourth century the draperies will be painted. The stelæ of Athens justify the presumption, and we might, moreover, invoke the testimony of a statuette of Artemis, found in Cyprus, a very carefully finished

[1] E. Robinson. The Hermes of Praxiteles and the Venus genitrix. Experiments in restoring the color of Greek sculpture, by Joseph Lindon Smith. Boston, 1892.

copy of an Attic original, of a date prior to that of the Hermes. The chiton is purple, the mantle green with a violet border, and the parts reserved for the painter have on purpose been left a little rough, in contrast with the fleshy parts, which are most carefully polished.[1] Let us complete the renewal of the painting of the accessories, and restore the gilding of the sandals, and we shall have an idea of a somewhat somber polychromy which, moreover, covers only a small part of the statue.

If we examine the details more carefully, the painting of the head suggests some thoughts deserving our attention. Where did the reddish brown of the hair stop? In the Hermes, as in several other statues by Praxiteles, the line of the hair on the brow is managed by a kind of plastic transition, by softened surfaces which the painter can not cut off brutally. We do not find here, as in archaic heads, that the sculptor's chisel has been at work abruptly cutting off the hair on the forehead and on the temples. The Roman copyists have instinctively felt the difficulty. In this point of view the female head of the Dresden Museum, which we mentioned above, is peculiarly interesting. The local tint of the hair is yellow; the curls are each marked off by dark-brown lines, which follow the outlines, and finally expire, so to say, on the forehead, forming thus at the root of the hair a kind of transparent fringe. No doubt a Nicias would have known how to solve that problem by simpler means, by a softening down of the tint, skillfully managed. But that is a question which practiced experiments alone can answer satisfactorily.

Were the eyes painted? If we had no other testimony to consult but Plato's, we should not hesitate to think so. Our impression would be confirmed by literary statements relative to the Venus of Cnidus. Could we understand that "hurried look," of which Lucian speaks, if the question was only of eyes without color and without life, such as we are accustomed to see in modern statuary? But we know that the custom of animating the look of statues by means of color is to a certain extent traditional in Greek statuary. Enameled eyes, inserted between the eyelids, sometimes set skillfully between two leaflets of bronze, the beard-like edges of which imitate the hair of the eyelids, are details which are more than once met with in archaic works.[2] A study of the technique of eyes in Greek statues led Mr. Conze to the conclusion that even in the best years of the art, the painting of the eyes is the rule.[3] The custom of hollowing out the pupil so as to give

[1]The statue has been published by Mr. R. von Schneider, Jahrbuch der kunsthist. Sammlungen des Kaiserhauses in Wien, V, Pls. I–II, page 1 et seq.

[2]Lechat, Bulletin de correspondance hellénique, 1890, page 361. Ballorn, Zeitschrift für bildende Kunst, 1893, pages 261–267. The Dresden Museum possesses an eye of a statue which is inserted in a bronze eggshell, and in which the colors of the iris and of the pupil are represented by marbles of different colors. (Arch. Anzeiger, 1889, p. 102.)

[3]Conze: Ueber Darstellung des menslichen Auges in der antiken Sculptur. (Comptes rendus de l'Académie de Berlin, 1892, p. 47.)

more intensity to the look is not anterior to the time of Hadrian, and this is a proof that polychromy is now beginning to abdicate. There can be no doubt that here, more than elsewhere, the individual sentiment of the painter found an opportunity to assert itself. An art as refined as that of the fourth century must have been more or less exacting, and if we look at statues like those of Praxiteles we become aware that the very structure of the eye, slightly veiled beneath the lid, warned the painter not to fall into brutal realism. In order to solve the difficulty, we may have to go back to the many colored head of the British Museum, in which the upper eyelid, cutting the circle of the apple of the eye, strangely softens the expression of the eye. But can we ever divine what charm the coworker of Praxiteles, so renowned for his women's portraits, may have succeeded in giving to the look of a marble Aphrodite?

Still, an objection presents itself here. We have before us the modeling of the hair, the eyes, no doubt also that of the lips, improved by colors applied with more or less delicacy, but always consistent enough to contrast with the tint of the marble, which is left untouched for all the bare parts. Is this not a shocking contrast? Will not the colors stand out with a certain crudeness? And do not the laws of harmony which the eye of a Greek perceives with such rare accuracy, impose upon the artist the duty of softening these violent contrasts, of subduing somewhat the too striking whiteness of the marble and to change it to a warmer scheme of colors? Here we come to a question that has been much discussed—the coloring of naked parts. Whether we admit it or not—and opinions are divided on this subject—one fact remains certain, the statue underwent a kind of treatment which restored the harmony between the parts that had been painted and those that the painter's brush had not yet touched. Thanks to written testimony, we know the details of this operation perfectly well. According to what Vitruvius says, it is the same which painters in encaustics practiced in order to give greater brilliancy to their painting, very much as we varnish a picture: "When the wall has been well polished and is very dry, we apply with a brush, made of pigs' bristles, a layer of Punic wax, melted before the fire and mixed with a little oil; then we heat the wall by means of charcoal kept in a chafing dish, until the wax melts and enters into the painting. Finally, the whole is rubbed with wax and clean linen, as we do with marble statues that are waxed." This is the operation which the Greeks call *γάνωσις*.[1] Other texts confirm the testimony of Vitruvius. The inventories of the temples of Delos allude to the *Κόσμησις* of statues of Artemisia and Hera: This is an operation resembling the *γάνωσις*, and consists in "spreading over the surface a coating to make it even, to polish it, to render it shining, or to color it,[2] or to wash it with certain substances which give it brilliancy

[1] This question is well treated by Henry Gros and Charles Henry in L'Encaustique et les autres procédés chez les Anciens. Paris: Librairie de l'Art, 1884.

[2] Homolle, Bulletin de correspondance hellénique, XIV, 1890, page 197.

and preserve it altogether." The accounts of expenses enumerate all the objects and ingredients that were employed—sponges; niter, doubtless for the washing of the statues and freeing it from dust when the question arose of refreshing the colors; white, carefully purified oil, wax, a stuff made of flax; finally a rose perfume, a very natural refinement when the marble represents "a statue that is to be worshiped and placed in a sanctuary." This operation was often repeated, and the duty of presiding at it devolved upon the officials of the temple. An inscription on the Ptoïon has preserved for us a statement of accounts made by one of the administrators of the temple of Apollo; it mentions, among others, a sum spent for the keeping of the statues and the removal of the γάνωσις.[1] It was still in use in the Roman period. Plutarch speaks of artists in marble who repair broken parts and restore them; he also mentions this fact that the first act of the censors, when they entered upon their duties, was to adjudge to the lowest bidder the feeding of the sacred geese on the capitol and the γάνωσις of the statue of Jupiter Capitolinus, because "the vermilion with which it had been the custom to coat the old statues very quickly underwent a change."

Thus very clear statements in writing justify us in supposing that this restoration was a treatment with wax, a transparent rubbing in, which protects the painted parts and the gildings, giving to the naked parts a soft sheen, a brightness resembling that of ivory, and satisfying the eye by softening too striking contrasts, while presenting to the sight nothing but skillfully managed transitions. But is the result really secured if the whole is nothing but a treatment without colors? The purified wax, of which Vitruvius speaks, the "white oil" which the inscriptions of Delos mention, can hardly have any coloring virtue, nor will they suffice to give warmth to the tone of the marble. This question also has been much discussed, and two suggestions have been made that are still open: Either, owing to a special preparation, the wax was giving a kind of yellowish tonality to the marble, or it was applied upon a very slight glazing, doing the duty of coloring matter. This latter hypothesis has been advocated by Mr. G. Treu,[2] and it must be admitted that it rests upon facts. The head in the British Museum lets us perceive a colored glazing beneath the treatment with wax, and this is therefore the proper place to recall that transparent rubbing in, which was observed upon the clouds on the "Sarcophagus of Alexander." It is, of course, easily understood that in most instances so very slight a glazing should have left no traces, and that Greek marbles show us only vestiges of opaque tones that have greater consistency. The restoration of so fragile, so fugitive a coloring remains a matter of

[1] Bulletin de correspondance hellénique, 1890, page 185. Article by Mr. Holleaux.

[2] Treu: Sollen wir unsere Statuen bemalen? and Jahrbuch des arch. Instituts, IV, 1889, page 18, and ff. Mr. Paul Girard adopts the same opinion in the chapter which he devotes to polychromy in La Peinture antique, page 283.

personal feeling. But we will never believe that the Greeks should at any time have sought to produce by such means the illusion of reality, and to represent actual flesh tints. We can readily imagine that a slight, very transparent rubbing in was given to the body of the Hermes, which allowed the grain of the marble to be discerned, and had no other object but to lend to the naked parts a warm and uniform tonality.

The ideal restoration which we have thus sketched will enable us to conclude in a few words. A writer who severely condemns the principle of polychromy, "the offspring of a savage instinct," quotes on this subject the following lines written by Diderot: "What would be the effect of the most truthful and the most beautiful coloring upon a painted statue? Bad, I think."[1] We do not contradict this. Besides—and we think we have made this sufficiently clear—this kind of polychromy is not at all in question. Among the Greeks, painting a statue was the result of a principle exactly opposite. Greek polychromy is, above all, conventional; it has never abandoned that character. We find it, at the very beginning, carry the principle of liberty within conventionality so far as to disregard the simplest probabilities purposely to limit the choice of colors and to make itself supple enough, far enough from all realistic imitation, to yield without scruples to the exactions of monumental polychromy. At a later period, when art had progressed, far from claiming to have conquered, it knows how to respect the noble material which artists use for their purposes, to play a subordinate part to sculpture and to lend it very discreet assistance. Its part to play is not, as has been said, to "attempt an impossible fraud," but to enhance the charms of a perfect form, which remains the mistress and the sovereign. For the same reason, it must always be a very delicate art, all in dainty tints, hostile to violent exaggerations, and well able to resist the temptations of realistic art. Now, when we admire the marvels produced by industrial art in Greece, the delicate coloring of the little figures (figurines) of terra cotta, the strikingly pure polychromy of ceramics with their white ground, we must highly honor the painters of statues. We do not exactly know what a work may have been in which a Praxiteles and a Nicias combined their efforts, but we do know that it required all the exquisite taste and all the science of a great master to realize in the Tanagra of our Luxemburg Museum the harmonious alliance of form and of color.

[1] Charles Blanc. La Grammaire des arts du dessin, page 432.

RELATION OF PRIMITIVE PEOPLES TO ENVIRONMENT, ILLUSTRATED BY AMERICAN EXAMPLES.[1]

By J. W. POWELL.

LADIES AND GENTLEMEN: I shall endeavor to explain to you the effect of environment on man. I shall try to demonstrate that primarily the environment has little effect on the physical man—that the principal effect, though not the whole of it, is on his mind. I wish to demonstrate to you that human evolution is intellectual evolution, in which it greatly differs from animal evolution. The neglect of this characteristic has come to us from the too exclusive study of the lower animals, so that the terms of evolution have been misapplied to man. I shall attempt to explain to you that human evolution is the evolution not of kinds of men, but of grades of men. The oak is a different kind of tree from the beech; the acorn, the plantlet, and the old oak are grades of the same thing. Now, clearly understand me when I speak of kinds and grades. Human evolution is serial evolution; it is evolution producing grades: animal evolution is primarily differential evolution producing kinds, while secondarily it produces grades. The laws of evolution do not produce kinds of men, but grades of men; and human evolution is intellectual, not physical. There are some slight exceptions to this, and in the early history of mankind some important exceptions; but gradually, as society advances, evolution into kinds is replaced by evolution into grades. Now, the effect of environment is only one of the factors of evolution, there being three: One is heredity, another is self-activity, and the last is environment; and we are to

[1]Saturday lecture in Assembly Hall of the United States National Museum, April 25, 1896.

The Saturday lectures, complimentary to the citizens of Washington, were continued during the season of 1896, under the auspices of the Joint Commission of the Scientific Societies of Washington, with the special coöperation of the Biological and Anthropological Societies.

The addresses were delivered in the lecture hall of the National Museum, 4.20 to 5.30 p. m., on the dates specified; several were illustrated by maps and diagrams, specimens, etc. The citizens of Washington and their friends were cordially invited to attend, and the attendance was good, the hall being always filled and sometimes crowded.

The series of lectures for 1896 was arranged with the view of illustrating the relations of life to environment, especially on the American Continent. Two courses

discuss especially this afternoon the effect of environment which produces kinds of animals but grades of men.

We will consider, then, the effect of an arctic temperature on animals and men. The fishes of an arctic climate acquire blubber and use it as a fuel in organic combustion. Many of the animals of the land and air do the same; some develop hair, or wool, as a protection from the storms; birds develop down. What effect will that arctic climate have upon man? He does not develop blubber like the whale; he does not develop wool like the ancient elephant; he does not develop down like the eider duck. What effect has the environment upon him? The effect is to stimulate his mental activities. He invents a house and builds it of blocks of ice. Then he invents fire and with it a lamp in which to burn the oil derived from the blubber of animals. Then he invents clothing and utilizes the furs of animals and the down of birds,

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were provided, the first pertaining chiefly to vegetal and animal life, the second to human life in its relations to lower organisms, as well as to the inorganic world. Special topics and lecturers were so selected as to present typical aspects of the general subject in the light of the latest researches, each lecturer being a recognized authority in his line of study.

Four of the lectures in the first course were already prepared for delivery or printing, and were arranged in such order as to form an introduction to the general subject of environmental relations; the address on the persistence of functionless structures was specially prepared for the course, but the copy was not completed when the author was called to Alaska.

The lectures constituting the second course were specially prepared by the respective lecturers.

The courses for the season were as follows:

FIRST COURSE.

Saturday, March 21.—The Battle of the Forest (illustrated). B. E. Fernow.

Saturday, March 28.—The Adaptation of Plants to the Desert (illustrated). F. V. Coville.

Saturday, April 4.—The Spread of the Rabbit (with illustrations of rabbit drives). T. S. Palmer.

Saturday, April 11.—Insect Mimicry (illustrated). L. O. Howard.

Saturday, April 18.—The Persistence of Functionless Structures. F. A. Lucas.

SECOND COURSE.

Saturday, April 25.—Relation of Primitive Peoples to Environment, Illustrated by American Examples. J. W. Powell.

Saturday, May 2.—The Dependence of Industrial Arts on Environment. O. T. Mason.

Saturday, May 9.—The Japanese Nation—A Typical Product of Environment. Gardiner G. Hubbard.

Saturday, May 16.—The Tusayan Ritual: A Study of the Influence of Environment on Aboriginal Cults. J. Walter Fewkes.

Saturday, May 23.—The Relations Between Institutions and Environment. W J McGee.

W J McGee,
G. Brown Goode,
J. Stanley-Brown,
Committee of Joint Commission on Saturday Lectures.

and instead of the environment affecting him he changes the environment. The whole process is reversed. The environment now becomes the creature of the man. He dresses in skins or in feathers, or in some other manner protects himself from cold. He builds his house and warms it, and that leads him to a multiplicity of other inventions. The whole effect of environment is to develop him intellectually, not physically.

Now, let us see the effect of environment in another region, another climate, and under other conditions. In temperate climes there are trees; he can not build of ice, for ice melts; so he builds homes of trees, of the slabs of trees, of young trees and of boughs; he weaves mats with which to cover his house, or he covers it with earth or leaves, as the environment suggests. He exercises his ingenuity in the devising of a habitation, and all the utensils of his home and the implements useful in his domestic life; thus he controls and becomes the creator of his environment instead of permitting his environment to change his physical constitution. He uses his intellect, and instead of merely developing as an animal would develop under those circumstances—herding on the plain, wandering in the forest—and changing his environment from one condition to another, he modifies and changes it. Human evolution thus, in so far as it is affected by environment in middle latitudes, is evolution of mind; it is not evolution of kinds of men, but of grades of mind.

A little farther south we come to an arid land where trees and other vegetation is scant, and where the rocks lie in profusion over the surface of the earth. Here man is thrown under another environment. The plant in an arid climate develops a bark or a skin which is covered with glaze, so that the water does not evaporate; then it provides organs by which water when it comes is stored within the plant, and a method by which this can be utilized when rain does not come. Life may be held in abeyance; the plant may sleep or partially sleep during the arid time, living only on stored water. It provides itself also with protecting organs to preserve it from destruction. In all of the arid lands plants are found to have a singular armature of spines and thorns and serrate edges, with which to save themselves from being devoured by animals. The animals also develop in a peculiar way. They not only have horns and spines, but several of them develop poisons, like that of the rattlesnake and of other reptiles and insects found in arid lands. But the effect upon man is altogether different; man does not develop poisons or horns, or a skin which can not perspire. He is not physically changed by reason of the arid climate; his organs as such are not greatly modified; there is no differential evolution in the man. The man now invents a house. Let us see how he does it. He takes these rocks that he finds scattered all over the land and builds him a house, perhaps under the cliffs where it will be shaded. He develops a great variety of houses, all adapted to the

conditions of the environment. Thus that environment affects his ingenuity—his intellectual powers; it makes grades of men, but does not make kinds of men. If he is in a region of volcanic rock, he takes the caves which are found, walls them in and makes houses. If he is in the region of overhanging cliffs, he puts outer walls in front of these cliffs and thus builds houses. If he finds tufaceous rocks, he excavates the tufa and cuts out cavate chambers within the tufa and he has a home. If he is in a region where stones can be piled up into walls, he builds pueblos with houses of stone walls. Now, he does not develop a poison as does the reptile and as does the insect, but he invents a club, a bow and an arrow, and finally, as he goes on through civilization, he invents firearms and all the wonderful appliances of war and fortification. In the progress of this development his mind is expanded, but the poor man himself as a physical being is one of the most helpless of creatures.

Let me call your attention to one more region of country. In southern Florida, along the shores of Yucatan and around the Gulf of Mexico and on the islands of the Caribbean, another set of habitations is discovered. Often the coral islands were used as the homes of the people of these lands. The coral islands, as they are found in nature, are swept by high tides, while in low tides they are uncovered. Such a tide-swept island was selected as a home and protected from the tides by low walls built around its margin. Through this wall the builders left a number of openings to the sea, the strait, or the lagoon. Then they dug canals from the wall into the central portion of the island, throwing the material up into ridges and providing many little canals and water courts, something like those of Venice. Into the water of the courts they drove palmetto logs as piles, and on these piles erected their houses. Then they could come from the strait into the center of the island with their boats and climb into their houses by ladders. These homes are found in vast numbers where coral islands have been utilized.

The animal develops long legs to walk in the water or webbed feet by which it can swim or gains a sac like the pelican in which it can store its food; but the environment has a different effect on man. It does not make different kinds, but different grades of men. The wolf by fighting gains long tusks. The rattlesnake by fighting gains poison. In all of the animal world contest effects a change in the physical constitution of the animal, but in human evolution contest, warfare, attack, and defense is by means of stratagem, and implements and devices are invented. Human evolution is always intellectual evolution, and it is never to any important extent physical. It is the evolution of the organ of mind—the brain. The advancement of man is serial instead of differential. Instead of affecting his body, the environment furnishes a subject about which he may think, and in this thinking and planning and inventing the man develops intellectually.

I wish to show just how evolution affects the human mind, and in order to do it I must explain to you that man develops in qualities, and only in grades of qualities. The difference which exists between man and man is not a question of properties, but only a question of qualities. If I make that clear to you, then I will make you understand what human evolution is.

Now, there are five properties of natural bodies. Bodies have number, bodies have extension, bodies have motion, bodies have duration, and animate bodies have judgment. But there is a difference between properties and qualities.

We set on a table a dozen apples in a tray. There are twenty men at the table. The number is a property of the apples. Here are twelve apples and twenty men sitting at the table. Twelve apples are few for twenty men. Suppose they are all taken by one man; the same twelve apples are many for that one man, few for many men. Many and few are qualities of things, and those qualities of things are always considered in relation to the purpose to which they are put. The twelve apples do not change as properties; the apples are the same in both cases; but instantaneously, according to the point of view, the many may become few and the few many. Thus, there are properties and qualities of number.

There are properties of extension or form; out of them are developed qualities of form. Here is a razor; it is sharp; the sharpness is a property of its form. A man shaves with this razor, and its quality is good for this purpose because it is sharp; another man seizes the razor to cut a throat; the quality now becomes horrible. Quality becomes good or evil in the purpose for which it is used. But there is no good or evil in the form itself. We do not blame the razor for being sharp, but we blame the intention of the man who uses it for the bad purpose.

Here is a car going by which has motion; that is a property. The car is fast; the electric car especially fast if you compare it with a horse car, but if you compare it with a railroad car its motion is slow; it depends upon the point of view whether its motion be fast or slow. Now, fall across the track and see it approach; it seems to come with a horrible velocity. You are in a hurry to go some place and you think the car is slow. The child at play thinks that time is swift; the old man weary with years thinks as he waits idly that the hour is very long. Whether the time is minutes or hours is a property; but whether it shall be long or short in our ideas is a quality.

In the same manner judgments may be good or evil; judgments by themselves as properties are correct or incorrect, but as qualities they are good or evil. Now, we have five kinds of properties and five kinds of qualities, and, curiously enough, properties of number develop into qualities of pleasure, properties of form develop into qualities of welfare, properties of force or motion develop into qualities of justice or injustice—qualities of conduct. Properties of duration develop into

qualities of wisdom, and properties of judgment develop into qualities of speech. There are five kinds of qualities in the world—qualities of pleasure, qualities of welfare, qualities of conduct, qualities of opinion, qualities of language; and this fact expresses the sum total of human activities.

The relations of properties are numbers developed by relations into kinds, or extensions developed by relations into forms, or motions developed by relations into forces, or durations developed by relations into times, or judgments developed by relations into ideas. Then, all of these properties are still further developed into qualities by their especial relations to human purposes; these qualities are arts, industries, institutions, opinions, and languages. It may be useful for us to illustrate and enforce the distinction between properties and qualities. Here is a mussel shell from the Ohio River. On the inside you see it has a beautiful nacre; hence it has color, which is a property, and it has beauty, which is a quality. The Indians once used these shells, cutting them into beads, and for this purpose they are beautiful; beauty is a quality. You see also that it has a form which is derived from its plan of extension, and it forms a cup. This form is a property; but the same Indians who used the shells for beads also used them for cups; as a cup it becomes useful, and usefulness is a quality. They also used this same shell as a knife or as a scraper, for it has a sharp edge, and can be used as a tool with which to cut or scrape, the force being derived from motion. Thus it has force in weight, strength, etc., which are properties. Again, it is advantageous to use the shell or scraper rather than many other things: for example, rather than a round stone or rather than a piece of wood. Thus advantage is a quality. But this same shell has duration: it will last long if buried in water or earth; it will last longer if it is kept in a dry place. This duration is a property, but if it is used as a knife for a purpose it will wear away more slowly than a stick or many other things that might be used as a knife or scraper; its endurance is a quality.

We have taken natural and inanimate objects for illustration, and found the four properties and four qualities; let us now take an artificial but inanimate object and see what we will find. Here is a pocketknife; the handle is white, the blades are steel color; these are properties; but it is a beautiful knife by reason of its pure white handle and its rustless blades; it is therefore beautiful, which is a quality. It has a form as a knife, and its blades are sharp because of their form. The form in the handle and the blades is a property, but the handle is useful and so wrought that it can be easily grasped and the blades are so sharp that they will cut. Here the handle and the blades become useful, which is a quality. It is a good knife for the purpose for which it is intended, as a pocketknife, but it would be a bad knife for the surgeon; in the form of a scalpel it would be good for his purpose. The knife is a good instrument for cutting a small bough, a bad instrument

for felling a tree. Goodness and badness are qualities. Again, the handle and blades of the knife have strength and other properties of force: but the same properties are also qualities, for the knife is good by reason of these properties for the purpose for which it is intended, but as a lever for rolling a stone it is bad. The knife has duration, which is a property, but it will endure for a longer or shorter time, depending upon the way in which it is used and the manner of its construction. This endurance for a purpose is a quality. Now we see that the handle of the knife has a rounded form with its edges beveled off, and the blade has one sharp edge, which is made so by grinding it; and more than that, the blade will close into the handle or open from the handle. Notice the handle of the knife carefully and you will see many characteristics that prove that it was wrought for a purpose; it therefore shows design. It expresses the judgment of the maker who manufactured it for a purpose. Thus we see pleasure in the knife in its beauty, welfare in the knife in its use, conduct in the knife when it is used to cut a pencil or cut a throat, wisdom in the knife in the way in which it is made. In all its properties and qualities it expresses these ideas, for it expresses the language of inanimate nature.

Let us contemplate a beautiful maiden with bright eyes, rosy cheeks, and lithe form. She is one individual; she has two eyes and two cheeks and many organs, and she is of another kind even than a bird. The hairs of her head, the eyes that sparkle, the cheeks that glow, and the lithe figure all have forms. She is a body of activities in all her members, and all of these are forces derived from motion. The maiden herself and all her organs have duration: she is a bundle of durations; but every moment of her life she is forming judgments by seeing, hearing, touching, tasting, smelling, and through her senses and all her mental powers acquiring knowledge, and her mind is a multiplicity of thoughts. These numbers or kinds, these extensions or forms, these durations or times, and these judgments or ideas are properties, but they may be all transformed into qualities by the mind. All of the multiplicity of properties may be transformed into qualities by the mind in our contemplation. One person would think the eyes beautiful, depending on experience, habit, or idea of the beautiful and ugly; another might be impressed by the complexion, according to the opinions with which the contemplating mind is endowed. A book might be written on all of these properties and their mutation into qualities.

The purposes for which men strive are pleasure, welfare, justice, wisdom, and expression. The activities which they develop for these purposes are arts, industries, institutions, learning, and language. In these purposes and activities qualities are involved, and qualities are good or bad by reason of the purposes. Things do not have qualities in themselves, but only as they relate to purposes.

All men have pleasures, some more, some less; all men have welfare, some more, some less; all men have justice, some more, some less; all

men have wisdom, some more, some less; all men have expression, some more, some less. If they have no speech of any kind, oral or sign language, or something or other, they have no opinions, they have no knowledge, they do not exercise conduct, they have no welfare, they have no pleasure. Now, then, let us look once more at these qualities.

I think I have made clear to you the difference between properties and qualities. But let me emphasize it a little more. I go on the street; I see a man rudely push another; I judge of his conduct and I am indignant; but the next moment I see that the man pushed was about to fall into a pit, and the other pushed him aside to save him, and so the quality of the action changes in my mind. Thus it is possible to change instantaneously our judgment of qualities, which always depends on the point of view. Properties are inherent in things themselves, and you can not change properties without changing the things themselves, but if you change the properties you change the qualities. If there are twenty men at the table and there are twelve apples, and if I change the number to twenty, few becomes plenty, but the plenty for the table is still few for a cargo. Now, all human activities are employed in change of properties of things for the purpose of changing their qualities. Hence, we are interested in the properties of things in order that we may improve their qualities. It is by these activities that men are so broadly differentiated—that there is such a wide gap between the lower animals and man. Man is slightly differentiated from the beast in his physical characteristics; still he is much like the monkey. He is broadly differentiated from the monkey by his intellect, which has been developed through his arts, industries, institutions, opinions, and language. In man there still exists a relic of his animal stage, for there are varieties of men, though not species. Men differ from one another. Some are dwarfs and others are giants, and there seem to be large and small races. Some men have long heads, others short heads, and there seem to be races that are more or less distinctive in the form of their crania. Some men are white, some yellow, and some black; some men have horizontal eyes and others oblique eyes; some men have straight and others curly hair, and yet in their characteristics are they varied. But these variations were mainly developed during the animal stage. Since they have become men these physical characteristics have been undergoing a process of obliteration, by reason of the admixture of streams of blood. You may find the white man and the black man, but there are many others; there are all grades between them. So you may find long heads and short heads, and there are all grades between them, and there are no hard and fast lines of distinction. Human evolution has wiped out the distinction.

In the consideration of human evolution primarily and fundamentally we must consider intellectual evolution. It is in vain that we study skulls, it is idle to study the color of the skin, it is folly to study the structure of the hair, it is inane to study the attitude of the eyes, for

man is more than the animal; his distinction is discovered in his intellect. To study men, therefore, we have to study mind, and to study human evolution we are compelled to study the development of the mind. All other questions, though important in considering man as an animal, are trivial when considering man as distinguished from the lower animal. How shall we study the mind? By studying the things which the mind produces through the agency of man's physical attributes. We are compelled to study the mind through a study of the pleasures which the mind has discovered and invented, through a study of the industries which mind has discovered and invented, through a study of the institutions which mind has discovered and invented, and through a study of the languages which the mind has discovered and invented. A wise man has said that the proper study of mankind is man, and man, above all other things, is mind; the proper study of mankind, then, is mind as it is exhibited in the five great classes of activities.

Let us once more consider these activities of culture. Animal pleasures are chiefly physical, though they would have no existence were the animals destitute of mind. They live to eat and drink, and they love the sports in which they engage. The activities of animals that depend upon flight for existence are changed into sports, and so lambs skip, so the kittens play at catching mice, so puppies play in mimic battles, so children play in imitation of their elders. The skipping of the child becomes an organized dance; the flight of the child becomes an organized race; the battle of the child becomes a game of ball; but these simple, childish pleasures develop into a vast system of pleasures. Man enhances his pleasures of food by the invention of condiments, his pleasures in the objects by which he is surrounded by the development of decoration, and the pleasures he takes in his daily life by the development of comforts, for he invents a chair upon which he sits, and a bed upon which he lies. His pleasures are still further evolved into the fine arts of music, sculpture, painting, poetry, dramatic representation, story, and religion. This is human evolution as distinct from animal evolution.

The industries of animals are employed in seeking and seizing food, in locomotion while passing from one environment to another to obtain food, shelter, and climate. But man soon learns to seek sustenance by cultivating food; to some extent he still seizes the natural food on the land, in the water, and in the air as an animal; but as man, he develops new sources of food by cultivating the soil and by domesticating animals, and thus results a multitude of food products. Instead of seeking the cave, or retiring to the deep water, or flying to a more genial climate when the seasons change, he invents a habitation and a vast multitude of utensils for his home and implements for his labor, and thus creates a supply which he does not find in nature. All this is a development of intellect and a modification of environment.

The animals control one another and engage in attack and defense,

and in his manner develop a vast multiplicity of organs and devices; so they have horns and tusks and hoofs and claws for attack, and scales and hair and thick skin and fleet legs and swift wings for defense. Man also develops implements and agencies for attack and defense; clubs, bows and arrows, guns, ammunition, fortifications, and all of the devices of warfare. More than that, and chiefly, he develops institutions, laws as rules of conduct, and sanctions to enforce these laws, and appoints officers of the law to see them executed. Thus, in modern society we find a vast system of institutions ramified in many directions and affecting all the conduct of all mankind. Human evolution is evolution in institutions; and warfare still exists as a relic developed from the animal condition.

Animals have opinions, but their opinions are mainly about physical things, and probably about very simple questions: human opinions immeasurably transcend animal opinions. Man's opinions about these things are evolved by a self-recognized endeavor to learn by observing the phenomena of objects in nature, comparing and discriminating and classifying them by the aid of language. He invents a multitude of methods of experimentation and verification by which he may gain certitudes. Further than that, he has opinions about pleasures which the animal can not enjoy; he has opinions about industries which the animal can not practice; he has opinions about institutions which the animals can not organize; he has opinions about opinions which the animal does not entertain, and, finally, he has opinions about language which the animals do not understand.

The lower animals express themselves to one another in all their characteristics; there is thus a natural language, and they utilize this natural language in a general sign language of designed expression. From this sign language, conscious of self and self-activities, the animal learns much of the environment: he knows his home and where his food is found and where safety may be sought, and a vast multitude of things, all learned by this crude sign language. But man proceeds further, and develops oral speech by a process of increments of invention; then he symbolizes oral speech with written speech, and far excels the animal in the expression of his opinions, and this is a characteristic which most clearly differentiates him from the lower animal. We may imperfectly distinguish man from animal by considering his physical constitution; but when we desire perfectly to distinguish him, we are compelled to consider his arts, his industries, his institutions, his opinions, and his language.

One potent environment has been purposely neglected in the previous statements. This is the social environment. We have seen that the physical environment has some slight effect upon the physical man and an indirect though profound effect upon his mind. Now, the social effect is direct, and this phase of the subject must be clearly expounded. The pleasures of the child are almost wholly social pleasures—pleasures

in which others cooperate and share. The game of "ring around a rosy" is a game for many; the game of ball is a game for many. In the pleasure of all decorations the many take part. In the fine arts, music is music for many, sculpture is sculpture for many, painting is painting for many, poetry is poetry for many, histrionic art is play for many, story is story for many, religion is worship for many. These are all for one, but at some time they are all for many. The one in the family develops through the agency of every member of the family, the one in the tribe develops in all of these activities through the agency of the whole tribe, the one in the state develops through the agency of the state, the one in the world develops through the agency of the whole social world; so culture passes from parent to child, and from child to child, and from tribe to tribe, and from nation to nation, spreading throughout the world. All culture has a personal factor, but it is only one of its factors which are multitudes in family, tribe, nation, and world. The development of mind by social environment can be illustrated by all of the activities of culture. Arts spread from land to land and modify one another, industries spread from land to land and modify one another, opinions spread from land to land and modify one another, and, finally, languages spread from land to land and modify one another. The way in which this is accomplished can be well illustrated by a consideration of languages, and the whole subject can thus be made plain.

There are many languages yet spoken in the world, but it is probable that a far greater number have been lost. It seems that man, in evolving from the animal state into the human state, developed a language within every little kinship tribe. As time went on primordial kinship groups were consolidated into larger and still larger tribes and finally into nations. With this change came a change in language; two primordial groups of primitive tribes uniting to form one compounded their languages. In the same manner any number of tribes might combine and their languages compound. This process resulted in the integration or unification of languages. When the united people separated, and one portion or the other migrated, gradually both of these divisions would associate with and become organized into tribes with other tribes speaking other languages. In this manner two distinct languages might be formed differing more or less from one another, because each great tribe was constituted of differing primordial tribal elements. Now, this would result in two languages only in part alike.

In time tribes come together and in time tribes separate; nations come together and nations separate, and the process of admixture of streams of blood results in an admixture of languages, so that at the present time in the study of one language we always discover two or more primeval languages, and the greater the culture the greater the number of primeval languages of which the given language is compounded. The Zuñi compose a little tribe in Arizona, only a few

hundred people speak the language, but it is not a primordial tribe nor has it a primordial language; at least two and probably several other primordial languages have been united to constitute the Zuñi language. The English language is composed of hundreds, perhaps thousands, of different languages; we know not how many. The German language is also composed of many primordial languages, but some of these languages are common to the English and to the German speaking people. The primary difference between the English and the German depends upon the elements of primordial languages of which they are composed and of the proportion of these languages which they have absorbed. All of the languages of the world that have been studied are found thus composite and to differ from one another in kinds chiefly because of the different elementary languages of which they are composed. If a people divide and separate into two or more distinct regions their languages scarcely change, they may be preserved and remain intelligible to all for hundreds or even thousands of years; but if two people divide, one going to one region and another to a different one, and in these regions mix with other tribes having other languages, compound languages will develop and will soon become barbaric or nonintelligible to each other. Now, the point which we wish to make is this, that by the effect of social environment kinds of languages are integrated, the total number gradually diminishing. The rate at which these languages diminish in number steadily increases with the progress of culture. It is probable that in America there were more than a thousand distinct languages when Columbus discovered the land, and these languages were so different that they could not be understood outside of the people to whom they belonged. With the progress of culture, many of these languages have been exterminated, and all are in rapid process of extermination. In a century or two they will all be lost. The invading people greatly outnumber the original inhabitants, and because they are dominating and controlling in culture the languages of these invading peoples will prevail, yet many words from the Indian tongues will be absorbed into the English, the German, the French, and the Spanish by the invader. While these Indian languages are still spoken, they are rapidly undergoing change, acquiring new terms and new grammatic forms by reason of the social environment to which the tribes are subjected, that is, by acculturation. Thus it is that languages chiefly develop by acculturation or social environment. The great fact never to be forgotten in the study and grouping of languages may be expressed as follows: *Languages have not differentiated from one primordial language, but have integrated from innumerable primordial languages.* One of the principal differences between these primordial languages seems to have been in phonics; warm climates tended to produce vocalic words, cold climates consonantal words; but this distinction becomes obscured with the progress of culture. Yet still the matter is but partly told.

There would be no language if there were not two or more persons striving to express themselves to one another.

Now, let us see how wonderfully language is involved in all other human activities. What pleasure would there be if there was but one person living? What pleasure would there be if there were many persons living who could not speak to each other? What welfare could one person secure from the world if there were no language? If there were no means of linguistic communication there would be no industries developed. What control could people exert over one another if they could not speak to one another? There would be no institutions organized. What wisdom would there be if we could not by language learn from another? Our opinions mainly depend upon our training. A man without language among men would be a fool, and a person who has no language, as oral speech, written speech, or touch speech is practically an idiot. By coordinate and contemporaneous development of all of these activities which I have described, man largely becomes the creature of the social environment and the modifier and creator of the physical environment. Animal evolution and human evolution are immeasurably distinct things. Man is man by reason of his mind, and his evolution is intellectual evolution.

INFLUENCE OF ENVIRONMENT UPON HUMAN INDUSTRIES OR ARTS.[1]

By Otis Tufton Mason.

THE ARTS OF LIFE.

My part in this programme is to speak to you upon the influence of environment upon human industries or arts.

By arts of life are meant all those activities which are performed by means of that large body of objects usually called apparatus, implements, tools, utensils, machines, or mechanical powers, in the utilization of force derived from the human body, from animals, and from natural agencies, such as gravity, wind, fire, steam, electricity, and the like.

There is a study of the activities of life that belongs to natural history, being concerned with what men are and what they do as mere animals. They eat, drink, sleep, walk about, and help themselves to the bounties of nature, regardless of race. Their bones, muscles, and vital organs in their adult state, in their growth from embryo to decay, in their specific forms, are to be studied alongside of and in comparison with the same parts of other creatures. These natural activities of mankind constitute what, in old-time writers, was the natural as distinguished from the renewed man. In reality, all these natural endowments, along with other matters of which I am to speak, form part of the occasioning environment of arts and industries. But our concern now is with inventions, artificial implements, processes, and results. We have to study culture or the doings of the artificial man—the renewed man. All that he does through new devices constitutes his industries or his true industrial life. The higher any subspecies or race or nation has climbed into this renewed life the greater has been its culture.

THE ENVIRONMENT OF ARTS.

The environment of arts is really the sum total of all that is outside of and in touch with them, including the whole earth and all that on it dwell, the sun and the planets also, and many of the stars, since men

[1] Saturday lecture in Assembly Hall of United States National Museum, May 2, 1896.

guide their journeys by them, set their clocks and adjust their calendars according to their movements, and invent the most delicate apparatus to gaze upon them.

Practically, however, the environment of human arts is the combined action of the sun, the moon, and the earth, especially at any given place or in any culture center.

When you look at a terrestrial globe the first thing you notice is its smoothness and homogeneity. Now, if the earth were as smooth and homogeneous, that would end the matter. There would have been no arts, no lectures on their relation to environment, no audiences, and, to make a long story very short, no environment worth speaking about. If you were to look closely at a globe you would see that it is painted to represent a great variety of facts about the earth, to declare its physiographic outlines and features, its roughness and heterogeneity. To be precise, the earth consists of three inclosures—the land, the water, the air—enveloped in the all-pervading ether. The solid portion may be called the geosphere, the liquid portion the hydrosphere, the gaseous portion the atmosphere. These are not so many distinct things, like a nest of encapsulating boxes, but there exists the most intimate associations among them; they environ one another. The geosphere invades the waters and the air. Nowhere are the waters and the atmosphere free from the invasion of solid particles of matter. The hydrosphere invades the other two, rising into the atmosphere in enormous quantities, and sinking into the earth to unknown distances. Finally, the atmosphere is found permeating the waters, making life possible, and finding its way deep into the structure of the solid crust. The components of the air and of the waters are also the chief ingredients in the structure of the solid portions. There is no element in the air nor in the waters that does not exist in another form in the earth's crust.

I speak of this to impress upon your minds the fact that this mother planet of ours is not a mere pile of substances without interest in one another, but a very carefully organized body to do a certain kind of work. I shall not now stop to inquire whether it was intelligently planned to do this wonderful work, of which I shall soon speak, or whether the work is simply the result of its cooperative activities. It will suit my present purpose if I can get you to see with me this marvelous set of terrestrial cooperations.

THE SUN AND THE ENVIRONMENT.

The sun in its relation to the geosphere, the hydrosphere, and the atmosphere forms a part of the environmental cooperations. Our distance from the source of heat and light and actinism, our curve and velocity about it and the speed of diurnal revolution, the degree of inclination of the earth's axis of revolution to the plane of its annual path, and, finally, our journey with the sun through space are all a part of one scheme or congeries of natural phenomena out of which the

minutest phases of our industrial life spring. By a simple diagram (see plate) this action of the sun and interaction of earth strata may be shown. The ancients divided phenomena into those of earth, water, air, fire—not a bad division when we are considering the influence of environment on human actions.

The terrestrial fires are responsible for the corrugations on the earth's crust. The solar fires, in cooperation with the moon and the earth's motions and its inclination in its orbit are responsible for the movements of the waters and the air in tides and climate and all the marvelous changes included in that word. The waters of the earth preserve tolerably well the spheroidal form, and the winds and climates of the seas conform to the simple laws of spherical motion under given conditions. The lands projecting from the seas by their elevations and conformations modify the movements of the air and the waters so as to re-create themselves. The winds of the Atlantic, saturated with moisture, sliding westward as the earth spins eastward at the rate of a thousand miles an hour, strike against the mountain barrier of the two Americas. Their waters are precipitated in deluges on the lowlands and blizzards of snow on the high mountains. This provokes the action of disintegrating frosts, of avalanches, of glaciers, of torrents, of rank vegetation to break down the mountains and form the continents eastward. On the contrary, west of this vast upheaval the winds from which the water has been wrung turn the western slopes almost to a desert.

The Eastern Hemisphere has other codes of behavior for the earth, the air, and the water. The results are the long slope toward the Arctic and a series of rivers whose mouths are stopped with ice at the moment when their higher channels are in the periods of inundation. The Russian and Siberian wastes are the result, and the long north sloping Piedmont from the North Sea to Lake Baikal.

These coordinating activities result in the rich rivers of China, the garden spot of Japan, the overwatered regions of southeastern Asia, the great desert region of central Asia, the varied climate of India, the excessively complex arrangement of elevation, heat, precipitation, and water front about southern and western Europe. In Africa and the Indo-Pacific Archipelagos the phenomena also form part of a single scheme.

To the arts of man all mountains, all rivers, forests, prairies, and deserts are necessary,—the deep sea no less than those prolific feeding grounds into which early men ventured and learned their first lesson in self-confidence, the end of which would come to be familiarity with the whole globe.

In fact, the whole world is now, and always has been, a single environment for man, fitted up with more or less spacious environments in which the first human groups settled, and as they became richer and stronger they took larger and larger apartments. Each one of these environments had a character of its own and the only possibility for a

race to occupy more than one was to become more and more artificial and to multiply its wants.

SPECIAL ENVIRONMENTS.

In this connection, it will be profitable to note how the cosmic forces have cooperated to create special environmental relationships in the three kingdoms of nature. The arts of mankind have to do with the mineral, vegetal, and animal resources of the earth, to procure them, to manufacture them, to transport them, to count, weigh, measure, and value them, to exchange them, and to enjoy them, in answer to an ever-increasing body of wants, working them as materials by means of tools and machinery, according to methods which constitute the processes of the arts, always with definite ends in view.

Now, these three kingdoms of nature, though they may have no king apparent to our senses, are far from being for our race a purposeless rabble. As with the three spheres of the earth, they also play into one another indefinitely under the sway of the imperial sun. This relationship has been represented as in the diagram (see plate).

In the case of the spheres, it was easy to see that if the earth were perfectly homogeneous and smooth the movements of air and water would be tolerably uniform; but as things are arranged this would not be so with our three kingdoms. There would be tropical, temperate, and arctic plants and animals even then. But with the present order of contours and movements in the atmosphere, hydrosphere, and geosphere, the kingdoms of minerals, vegetables, and animals undergo an endless variety of changes, creating no end of subvarieties in the environments and stimuli to action and artificial life.

The mineral kingdom is awakened by the sun; not only its mechanical movements are quickened in the air, the water, and the earth, the currents of the ocean, the rains, snows, ice, frost, and heat, but somehow his beams are entangled with life itself, for only in his presence are the fields and forests clad in emerald, the organs of regeneration made resplendent in flowers of every possible hue, and new beings come into life at his bidding. It is only in the unfathomable abysses and in the unillumined earth that life is not. The stream of life flows into the vegetal kingdom through the mineral, and a return current brings liberated oxygen and the products of decay. The stream of life flows from the vegetal into the mineral with return currents of carbonic acid gas, decayed matter, and the preparation of the soil. The stream of life descends from the animal to the mineral, with return currents in the form of air to breathe, water to drink, and a host of mineral substances wrought into our blood, brains, and bones.[1] The invisible

[1] Dr. C. Hart Merriam's studies in the relation of fauna to annual heat units is interesting in this connection, since they really stand for the total solar force, luminous, actinic and heating. (Smithsonian Report, 1891, pp. 365–415.)

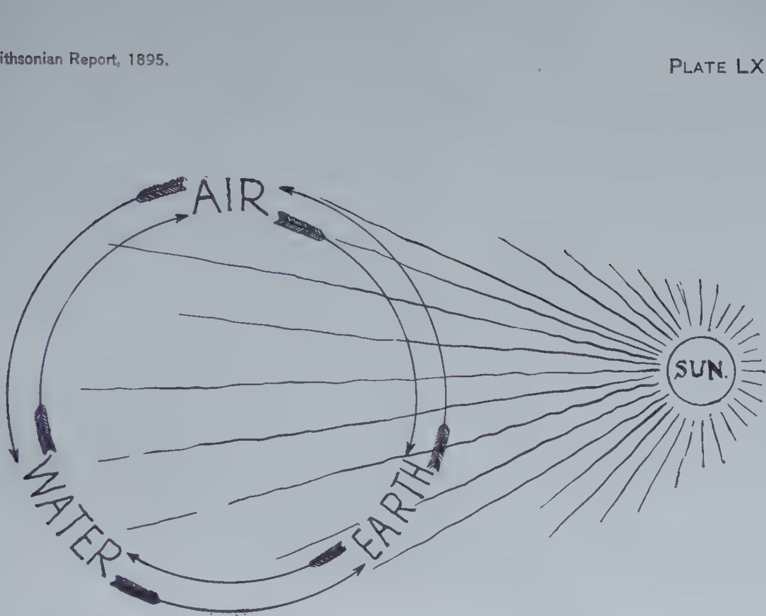


FIG. 1. Chart showing how the sun, operating on the geosphere, the hydrosphere, and the atmosphere, makes of them a single environment for the whole human species. The air invades the earth and the waters; the waters invade the earth and the air; the earth invades the waters and the air. Their mutual activities depend upon the sun.

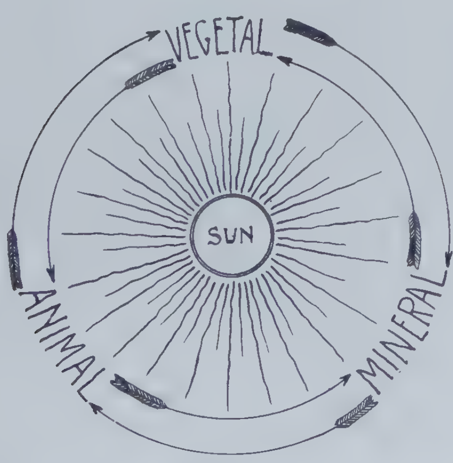


FIG. 2. Showing how the three kingdoms of nature are in their totalities under the rule of the sun and how their interdependencies are created by that luminary, the whole constituting a single environment of man.

motions produced by the sun's force becomes visible in the rising vapors; the motions of the air in the movements of the clouds; the secret motions of the snow and rain, the dew and the frost in the downward movement of the lands; the unseen movements of the land appear in the families, genera, and species of animals; finally, the distribution of these reveal themselves in ways not known to us in the specific cultures of mankind belonging to the areas where they arose.

Do you not see that the total result of these natural activities gives us a world that almost mimics a thoughtful being, with something to bestow, many things to suggest, power unlimited to lend, and, mark me, an intelligent discrimination of rewards and punishments whose effect has been to glorify the good and to destroy the unfit.

I do not say that the world is alive and thoughtful, that its provinces or areas of separate environmental characterizations are each governed by a viceroy, but the law of the ingenious mind of man working in these makes it appear so. His subjective activity is projected upon the background of the earth, until it is quite certain that he is in cooperation with the power that governs it. It is not yet decided how far this force obtrudes itself upon his will, since it is certain that his conservatism impels him to certain activities against the environment.

KINDS OF ACTIVITIES.

There are six kinds of human industrial arts as regards the environment, to wit:

(1) Taking the gifts of nature: Man is then a quarryman or miner, a gleaner, a fisherman, a hunter, and later a domesticator.

(2) Changing the form of natural objects: Man is then a manufacturer, mechanic, artisan, an inventor of tools and machines.

(3) Changing the place or position of himself and of things: Man is then a traveler, a carrier, an engineer, a subduer of force.

(4) Intelligent accounting for things and measuring: Man is then a statistician, a measurer, surveyor, gauger, weigher, a maker of clocks and almanacs, a scientific explorer.

(5) The exchanging of the fruits of labor, commerce, business, money: Man becomes a merchant.

(6) The arts of enjoyment: Man becomes a user of food, houses, furniture, utensils, equipage, fine art in all its branches.

It is certain that we are brought into relation with nature or environment in and by all of these. Indeed, it is due to the great diversity of environments that they are all possible. If you will run your eye along the perspective of human history, you will see cultures running into one another like the streams of a river or the lines of a great structure. Each culture was developed in a special environment. The union of two environments eventuates in the union of two cultures, widening both.

CHARACTERISTICS OF ENVIRONMENT.

We may now be allowed to enumerate some of those characteristics of this composite nature of things whose influence upon our daily activities we are now contemplating. And first we can not help seeing that the environment is the provider of all raw materials. This seems trite, and in its simple statement may be so. But see how each people of the earth is characterized by its raw materials. An Eskimo collection is white; the same ideas are expressed by the Haidas south of them in jet black. The art of the British Columbian is red, of Oregon and California yellow, of the Pueblos écru, of Mexico gray. All this is plain enough when you know the color of walrus ivory, of slate, and mountain goat horn, of cedar, of grasses and spruce root, of fire clay when baked, and of volcanic building stones. People express themselves in the material at hand. The Egyptian was furnished with limestone and syenite, so he hammered away at that. His ideas could mount no higher than the material. On the other hand, the Greek was provided by environment with the whitest, finest, and thickest quarries of marble on earth. It was expected of him that he should give the highest expression of the æsthetic faculty in sculpture and architecture, though his pottery was somewhat inferior. When the whole world is brought into one environment by the art of transportation, then other lands have hope to imbibe some of the genius engendered and fostered about the quarries of Pentelicus. But in the generative period of industrial forms, before the world-embracing commerce, it was not so.

Nature or environment appears to us, secondly, in the light of a purveyor of force. At first our race had only the force of its own frail but versatile bodies to depend upon, yet men will never cease to marvel at this mechanism as an economic device for storing and utilizing power. Whether we regard a machine in the light of saving fuel, of speed, of ability to change rectilinear motion readily into that of any curve or succession of curves, the body of man will ever remain for inventors to wonder at and imitate. Long ago backs and hands and feet were wearied with ever-increasing burdens, and so the dog, the reindeer, the horse, the ass, the cow, the camel, the llama, the elephant, and even the sheep were handed over in innumerable packs and herds to give additional power to industry. These creatures not only fed and clothed men, they made men's legs longer, their backs stronger, their hands more skillful. Then came the wind to blow upon the mat, the sail, the mill, and the water, moving in its natural currents and then in artificial channels to turn the wheels of industrialism. How bountiful has nature been in the supply of force! Who ever dreamed of exhausting it? How many ships upon the sea would it take to use up all the winds that blow, and how many turbine wheels would it

require to take up and transform into useful arts the force of all waterfalls?

It is true there are environmental gifts that may be ruthlessly wasted. As Professor McGee has shown, the resources of fertility wasted in the United States every year exceed those reproduced in crops. Six hundred million tons of coal are the output annually in the United States. Many species of most useful animals have been irretrievably extinguished, but who ever thought of exhausting gravity, elasticity, the mechanical powers, the forces of the environment. However, we must admit that even these natural forces are unequally distributed, and that gives character also to the arts. There are no turbine wheels in the desert, no sails cross the zone of calms, and each domestic animal has its geographic range beyond which it becomes unprofitable.

In the third place, the environment manifests itself as the teacher of industries. I should be the last person in the world to rob the ingenious mind of man of its glory in achievements through human industry; but the fact remains that wherever you enter his workshop, called the world, you will see hanging on the walls and lying about him all sorts of patterns and models, and a multitude of processes are going on which he falls into as "heir of all the ages."

There were cave dwellers before there were men; spiders, mud wasps, beavers, and birds spun and worked in clay and cut down trees and made soft beds for their young long ago. Plants reared vessels and mollusks produced dishes that even now are the patterns of the most skillful potters. There were hammers, gimlets, pins, needles, saws, baskets, and sandpaper at hand when the human artisan first became an apprentice. And I would ask you whether there is any possibility of this suggestiveness of nature ever being exhausted. Whisperings are yet going on in her school. The little birds have not told all the secrets. The processions toward the patent office prove that the growing coordinations of environment in relation to the common industries have turned the village school, with its circumscribed advantages, into a world-embracing university.

Lastly, I must not fail to tell you that the environment itself is capable of unlimited education and improvement in relation to the commonest wants of life and our ways of satisfying them. There is one thought about the nature of the common things among which we mingle that fills me with ever-increasing delight. It is the sympathetic response of nature or environment to every affectionate touch. An industrious and wise farmer settles upon a piece of land. Soon you behold remunerative crops replacing the forest and the waste. The man is enriched; he then enriches the land, and by a kind of mutual admiration they two grow fat together. When a progressive race has settled down in a part of the earth not too icy, not too torrid, not

discouragingly luxuriant, not absolutely a desert, the same has been true. The wild and cooperatively relentless wolves have become faithful dogs. The capability was slumbering there. The feeble grasses are transformed simply by giving the best a chance into prolific grains. The modest wild flower becomes the florist's delight, landscape gardening the composite expression of all æsthetic pleasures in form, color, number, odor, and motion. Professor McGee has called our attention to the partial desert as the best possible arena for starting certain forms or epochs of this artificial life which we are now considering, and it is. Indeed, in this perfectibility of the environment of which I am now speaking it seems to be the manifest destiny, the natural proclivity, the ambition of the desert to blossom as the rose. How delightful to contemplate this readiness of nature to respond to the touch of man.

AMERICAN ENVIRONMENTS.

It must have frequently occurred to my hearers that the more circumscribed the environment the more dependent the activity must be upon it and therefore the more monotonous the life must have been. This is true in the kingdoms of life and also true as among genera and species of animals. It has been also true among the races of men. The best examples, therefore, of environment affecting arts and industries will be found where the tribes are still living in the endogamic stage of social culture, so that the happy arrangement between the arts and their surroundings have been as little disturbed as possible. Taking the Americas at the time when they were first revealed to the historian you will find that they range through natural conditions diversified enough to bring into prominence arts adapted to each culture area and obtrusively different from those of other areas.[1]

For our present purpose, there may be said to have been eighteen American Indian environments or culture areas, to wit: Arctic, Athapascan, Algonquian, Iroquoian, Muskhogean, Plains of the Great West, North Pacific Coast, Columbia drainage, Interior Basin, California-Oregon, Pueblo, Middle American, Antillean, South American Cordilleran, Andean Atlantic Slope, Eastern Brazilian, Central Brazilian, Argentine-Patagonian, Fuegian.[2] These will be given seriatim with the factors constituting the motives and processes of the arts of life. A table will follow with the factors at the top. By writing the characteristics of each factor for each environment you would have at a glance

[1]These culture areas should be compared with Major Powell's linguistic map, 7th An. Rep. Bur. Ethnol., with Thomas's mound maps, 12th An. Rep. Bur. Ethnol., with Bancroft's geographic areas in his Native Races of the Pacific States, but especially with Franz Boas's Anthropology of the North American Indians, Mon. Internat. Cong. of Anthrop., Chicago; C. Hart Merriam's Geographic Distribution of Life in North America, Smithsonian Report, 1891, and J. A. Allen's Geographic Distribution of North American Mammals, Bull. Am. Mus. Nat. Hist., New York, Vol. IV.

[2]See Powell (J. W.), 7th An. Rep. Bur. Ethnol.; Brinton (D. G.), The American Race, New York, 1891.

the whole result of our inquiry. This elaboration may be tabulated to any degree of minuteness, but for the present we must be satisfied with—

(1) Climate and physiography;
(2) Predominant minerals, vegetables, animals;
(3) Foods, drinks, narcotics, stimulants, medicines;
(4) Clothing and adornment of the body;
(5) House, fire, furniture, utensils;
(6) Arts in stone, clay, plants, animal tissues;
(7) Implements and utensils of fishing, hunting, and war;
(8) Locomotion.

ENVIRONMENTS AND CHARACTERISTICS.

The Arctic environment, according to the eight classes of characteristics laid down, may be thus defined as having—

(1) Intensely cold climate, six months day and six months night, abundance of ice and snow, no vertical zones, much water line and level coast.

(2) Chert, slate, soapstone, pectolite; driftwood, wreckage, no timber, berries; aquatic invertebrates, mammals and birds, reindeer, land carnivores, and rodents.

(3) Little vegetable diet, meat of fish, birds, aquatic mammals, and deer; pipe and snuff introduced.

(4) Dress of furs, birdskins and intestines, labrets and tattooing.

(5) Underground houses or igloos, snow house, stone lamp-stove, steamed wood for dishes.

(6) Chipping, sawing, boring, grinding, and carving stone; carving bone, antler and ivory; a little pottery at Bristol Bay; needle in basketry, sinew twining and braiding, tailoring in skins; ingenious weapon makers.

(7) Hunting implements, harpoons, bird darts, fish darts, lances, fish hooks, nets, composite bows and arrows.

(8) For travel, poor snowshoes, ice creepers, sleds, kayaks, umiaks.

The Athapascan environment has the following characteristics:

(1) The drainage of the Yukon and the Mackenzie and the barren ground southward to British Columbia.

(2) Poor in the industrial minerals; birch, conifers, and poplars; fish, birds, caribou, bear, and fur animals in profusion.

(3) Fish, meat, berries, cooked by boiling with hot stones or roasted.

(4) Deerskin clothing, with or without fur, bonnet, shirt, pantaloons, moccasins; much ornamented; no tattooing.

(5) Bark lodge, movable; bark and basketry dishes; fur bedding; open fire.

(6) Manufacture of hunting implements, basketry, bark work; excellent skin working; no pottery.

(7) Plain bows, arrows with bone heads, lances, fishing nets and hooks, gigs.

(8) Snowshoes of finest webbing, sleds, bark canoes.

The Algonquin-Iroquois characteristics of environment are:

(1) Climate temperate to subarctic; wide expanse of lowland; extensive inland waters and indented Atlantic coast.

(2) Materials for industry, quartzite, diorite, sandstone, etc., for chipping, battering, and polishing, and mines of jasper, copper, and steatite; hard wood, birch, conifers, wild rice; game birds and mammals, fish, mollusks.

(3) Dietary of great variety in the animal products of land, fresh water, and salt water; maize, pumpkins, beans, natural fruits; boiling with stones or in pots, roasting; tobacco pipe.

(4) Shirt, breech clout, leggings, moccasins of tawed skin, in winter fur clothing; body frequently exposed in the southern part of the area.

(5) Dwellings of bark lodges, skin lodges, bark and skin long houses or arbors, communal barracks, village camps; fires in center; little furniture; extensive use of mats woven or sewed together, and skin robes. In this area there are the largest number of geometric earthworks, fortifications, mounds, and shell heaps.

(6) The arts were not of high order; they included chipped, battered, and polished stone; poor, red pottery; bark, dugout, and wicker vessels: quill work; tawed skin, sinew, and thong or babiche work; mortar grinding.

(7) The weapons of war and capture were clubs, stone knives, lances, plain bow and stone-pointed arrows, barbed spears, fish pounds, traps, hooks, gigs, scalps were taken.

(8) They traveled afoot, along well-known trails, on snowshoes in Canada; on the water in birch canoes or in dugouts; portages.

The Muskhogean area includes the Southern States of the Union below the northern boundary of Carolina. In it were other tribes and parts of Northern families, but the area dominated the activities of all.

(1) Low mountains, rich river valleys, abundant rain, ocean and gulf coast, climate temperate to subtropical.

(2) River gravels, and mines of flint, mica, and copper; abundant timber, cane, tobacco, and natural fruits; deer, turkeys and other birds, fish and aquatic invertebrates in profusion.

(3) Food of maize, melons, pulse, fruits, the products of the chase, and the rich harvest of the waters; roasting, pot boiling, baking in hot ashes, smoked and fire-dried food.

(4) The dress of this area was partly of tawed skins, little clothing was worn, in fact. The caves reveal capes and petticoats of bast and native hemp, woven and fringed. Feather work, shell beadwork, and pearls were used in profusion.

(5) They lived in small huts and grass lodges and in wattled houses daubed with mud. These were collected in fortified villages. The furniture was of cane and matting, vessels of clay and diagonal basketry; open fire. Here abound geometric mounds and earthworks, shell heaps, and shell mounds.

(6) The arts were chipping, pecking, and polishing stone; pottery making of a distinct school; twined and plaited textiles of cane and native hemp; feather working; grinding in log mortars.

(7) The weapons of capture and war were plain bows, reed arrows, reed knives, stone tomahawks, lances with stone points, clubs for braining.

(8) Traveling on foot, and packing; on water were used canoes hollowed from the soft poplar and gum trees, which are abundant.

The plains of the Great West have constituted a definite culture area characterized by—

(1) A piedmont sloping down to the immense prairies of the Missouri, the Platte, and the Arkansas; temperate climate.

(2) Few good industrial minerals and those prized and guarded by intertribal agreements; plants restricted to small trees for tent poles, arms and cradles, apocynum for textiles; buffalo overwhelmingly.

(3) The dietary was meat flavored and supplemented with berries; kinnikinic; no farming.

(4) Skin clothing in excess, hood, shirt, clout, leggings, moccasins, robes; paint the body.

(5) Skin lodges in circles; earth lodges like those south; furniture of hides, fur, and intestines; dung for fuel; jerked meat; stone boiling in small pits lined with rawhide; roasting.

(6) Stone chipping, pecking, carving, and polishing a little; skin dressing, tailoring, embroidery in quill, spinning flax without spindle occupied the entire time of the women. The men were hunters preeminently.

(7) The weapons of capture and of war were compound, sinew-backed, and self-bows, and stone pointed arrows, stone tomahawks and casse-tetes, clubs armed with jagged blades, lances.

(8) Travel was on foot and the dog was a beast of burden; for crossing rivers the bull boat or buffalo-hide coracle was ever at hand.

The North Pacific area extends from Mount St. Elias to the Straits of Fuca, embracing Tlingit (Koloschan), Haida (Skittagetan), Tsimshian, and Nutka, or Wakashan, tribes. Its characteristics are:

(1) Moist, temperate climate; archipelagic and mountainous coast.

(2) Its material resources are slate and granular rocks, immense forests of conifers, sea fauna inexhaustible by savages, herring, salmon, halibut, oolachon, mollusks of great size.

(3) Fish diet, mixed with fruits; no grain; snuff and tobacco; stone boiling and roasting.

(4) Woven clothing of goat, sheep, and dog hair and cedar bark; labrets and tattooing.

(5) Their dwellings were communal barracks, with totem posts; central fires; furniture and utensils of stone, wood dugout, woven bark, and exquisite twined and checker basketry.

(6) Their arts were stone carving by battering and scraping, no chipping; wood carving, twined and plain weaving; no pottery.

(7) The weapons of war and capture were retrieving harpoons, gigs, and the like; fish traps, clubs, few appliances for land animals.

(8) They traveled in dugout canoes altogether, keeping close to shores and water courses. At the extreme north the fine snowshoe, borrowed from the Athapascan, was in vogue.

The Columbia drainage area includes the entire basin of that stream and some contiguous patches. It is very different from the foregoing, having the following characteristics:

(1) Stern, islandless coast, but prolific tide water and streams; rich lands; mild climate.

(2) Its material resources for savagery are siliceous and granular rocks; textile plants and forest quite varied; salmon and waterfowl; abundance of edible roots and fruits.

(3) Their dietary included fish and mollusk, with camass, kouse, and other roots and fruits in abundance; no agriculture; stone boiling and pit roasting.

(4) The tribes dressed partly in skins, partly in textile garments, but the mild climate allowed them to expose their bodies much.

(5) Their houses were likewise communal barracks, with interior inclosures, but the huge totem post is lacking; furniture of greatly varied matting, wallets, rigid baskets.

(6) The arts were chipping and battering stone; no pottery; many types of weaving and basketry, including plain, checker, diagonal, twined bird cage, coiled meshes, and stitches; an exceedingly mixed region.

(7) Their weapons of capture and war were bows and arrows, harpoons, lances, clubs, hooks, and traps.

(8) They traveled in bark canoes, Amoor type, and near the salt water in excellent dugouts. On foot in winter they used coarse snowshoes.

The interior basin of the United States includes the lands between the western slopes of the Rockies and the eastern slopes of the Sierras. It lies north of New Mexico and Arizona, and includes the most of Colorado, Utah, Nevada, eastern Oregon, Idaho, and a corner of Wyoming. Its characteristics are:

(1) Partial deserts among mountains with rich and wooded patches.

(2) Materials for savage arts, siliceous and friable stone, deer, antelope, and other game, few fish, nutritious plants, poor timber, and textile plants.

(3) Diet meager, meat scarce, bread, mush, and soups of acorns and wild plant seeds; insects and grubs eaten; cooking with hot stones and roasting or parching in trays with hot stones.

(4) Buckskin shirts, clouts, leggins, moccasin excellent, hats of coarse, twined basketry; no tattooing.

(5) Shelters of brush by the side of bluffs or in the open; partial cave dwellers; stick beds, vessels of basketry dipped in pitch; no pottery; fire out of doors.

(6) Chipping stone, good skin dressers, basketry in twined ware, rough and coarse by reason of the material; excellent gleaners and millers.

(7) Their weapons are sinew-backed bows, short, stone-pointed arrows, clubs, and land nets.

(8) Traveling on foot, no artificial appliances for land or water; carrying in conical baskets by means of headband.

The Californian-Oregon area embraces a part of Oregon and all of California, except the southeastern third. Its characteristics are:

(1) A series of short and isolated valleys, descending to the ocean, and without harbors, or to San Francisco Bay. Though there are mountains, there are no vertical zones of culture. The climate is vigorous and salubrious. The isolation is obtrusively shown in the fact that here twenty-six linguistic families were packed.

(2) Materials for arts were siliceous stones for chipping, superb; no fictile clay; fibers, fruits, and woods excellent; fish and game plentiful.

(3) Diet of acorns, seeds, fish, birds, and mammals. Cooking with hot stones in mush and in pits; open roastry; tubular pipes.

(4) Dress of buckskin, rabbitskin, and grass fringes, scanty; tattooing.

(5) Insignificant shelters, varied, partly below ground; granary baskets; shell heaps.

(6) Stone chipping admirable; stone and basketry mortars; basketry of every type in seven distinct species of weaving; flax twine.

(7) Weapons, neatly made sinew-backed bows and elegant arrows in many styles, with most delicate stone points; fish spears, retrieving arrows, fish and animal traps.

(8) Poor boats; rafts and balsas in the south; snowshoes rare and rude; conical baskets and carrying bands.

The Pueblo culture area includes New Mexico and Arizona, with extensions into Utah, southern California, and northern Mexico. Its characteristics are:

(1) Arid, hot climate, elevated mesas, canyons, irrigable valleys, mountains.

(2) Materials of industry, shales, clays, turquoise, volcanic rocks; mesquite, oak, cottonwood, yucca, basket shrubs, cultivated foods, and fruits; deer, rabbits, goat, mountain lion, coyote.

(3) Maize, pulse, melons; little meat until the introduction of sheep; griddle cakes, mush, and pottage; cigarettes.

(4) The clothing is somewhat scant, for a long time of buckskin and woven fabrics, formerly rabbit-skin robes, feather robes, weaving in apocynum and agave fiber, paints, no tattooing.

(5) Pueblos, either underground, crater, cave, cavate, cliff, mesa, or lowland; towers.

(6) Chipping, polishing, and boring stone; smooth and painted pottery in great profusion; mythological in motive; basketry in wicker, diagonal, twined, and coiled ware; weaving in frames and with grating harness, in plain and diaper; wrapped ornamentation; bone and horn work rude; mealing stones in sets; sand painting, irrigation.

(7) Weapons of war and the chase were bows and arrows, shields, rabbit clubs for throwing, land nets, clubs.

(8) On foot only, no conveyance by land or by sea; carrying on the head with ring, or on the back with forehead band.

Middle American culture area, including southern Mexico and Central America. The characteristics are:

(1) Mountains, terraces, and table-lands; vertical zones of climate from torrid seacoast to temperate uplands; wet and dry season; no good harbors; culture forces centrifugal.

(2) Materials are obsidian, volcanic building stone, gems; yuccas, agaves, excellent timber, cotton, food plants; animals inferior, abundance of beautiful birds, fish and shellfish on the coast.

(3) Food largely artificial, of maize, pulse, flesh, fish, chile in many forms; chocolate, pulque.

(4) Sandals of fiber, scanty body garb of poncho and serape, straw hats, feather clothing superb, labrets.

(5) Thatched hut, open fire, hammock, pyramids, great buildings of hammer-dressed and carved stone; vessels of gourd and clay.

(6) The arts were mining, metallurgy, stone cutting, gem cutting, grotesquely modeled pottery, loom weaving, netting, feather embroidery, gourd work, metate milling, paper and bark cloth; irrigation.

(7) Weapons were atlatl and spear, bladed clubs, obsidian daggers, bow and sling not prominent.

(8) Dugouts and reed floats, canals, professional carriers, headband and breastband.

Antillean or insular area, called also the West Indies. To this region belongs also southern Florida, a portion of the northern coast of South America:

(1) Perpetual summer (77° to 82° F.); mountainous insular areas in deep, clear sea; currents northwestward; islands easily accessible one from another.

(2) Granular stone, little for chipping, great canoe trees, cacao; mollusks and fish; great mammals, none.

(3) Dietary of manioc, sweet potato, cacao, fish, iguana, turtles; snuff and cigarettes.

(4) Clothing meager, of vegetal fiber wholly.

(5) Thatched shelters near the sea chiefly, pile dwellings, hammocks, no storage, open fires, and hammock fires.

(6) The arts of Antillean peoples: Excellent carving and polishing of stone and wood; red pottery rudely modeled and engraved; diagonal weaving, metate grinding, canoe making.

(7) Weapons were spears, clubs, tomahawks, with celt in perforated handle.

(8) Sandals for foot travel, dugout canoes; carrying on the head, perhaps introduced from Africa.

South American mountain or Cordilleran culture area, including the

mountains and especially the Pacific slope of Colombia, Ecuador, and Peru. The families of Indians were those usually called civilized. The characteristics are:

(1) Elevated and continuous plateaus broken here and there by lofty mountains, beneath the plateaus vertical zones of climate; generally arid, desert in the south; gorges in the west slope, coast plain little indented; culture forces centripetal.

(2) Materials of arts, volcanic, architectural rocks, gold and silver; coca, reeds, cinchona, cacao, maize, potato, beans, fish, llama, guanaco, vicunya, paco; timber scarce.

(3) Food of frozen potatoes on the plateau; maize, beans, meat, fish, lower down. Coca is chewed to economize strength.

(4) The clothing was woven stuffs of llama wool and cotton, fine in quality and characteristically figured; sandals.

(5) The buildings were thatched huts in fortified villages, furnished with hammocks or beds on the ground; open fire, dung fuel, griddle and pot cooking.

(6) The arts were hammering and carving of stone, building with huge blocks, metallurgy, pottery modeling and molding; diagonal, twilled, and open weaving; irrigation, quipu.

(7) Stone-headed club, sling, wooden saber.

(8) Traveling afoot, or on balsas of logs or reeds; carrying on human backs or llamas, post roads and suspension bridges.

Andean Atlantic slope, including the eastern margin of Colombia, Ecuador, Peru, and Bolivia. It is in fact the loop in which arise the great rivers that feed the Amazon. Its characteristics are:

(1) A tropical piedmont, sloping eastward, profusely watered and forested.

(2) Its resources for culture have been little studied; mineral substances are little used; the vegetation is absolutely overpowering.

(3) The food of the scanty population is fish, monkeys, peccary, and such natural fruits as may be found.

(4) Little or no costume was anciently worn, except in the form of ornament, which consisted of gorgeous plumage of birds sewed to bark cloth and teeth and pretty seeds and wings of gorgeous beetles strung in armlets, leglets, and necklaces.

(5) Wooden houses thatched with palm leaf were the habitations, with sleeping bunks.

(6) The arts of life were those of savagery alone; little agriculture was known. To hunt, to fish, to war, to combat nature and one another was their continuous occupation. They were good woodworkers and feather workers; had no pottery.

(7) Weapons in this area were and are blow tubes and poisoned arrows, rectangular sectioned, long bows, shields, trident lances, throwing sticks, drum signals, dried heads, ourari.

(8) Travel afoot in the forests, now using the ever faithful machete; use headband in carrying; water travel in canoes down the cataracts of the upper rivers.

Eastern Brazilian area, from the Tocantins River eastward. The characteristics of this area are:

(1) Tropical climate, elevated table-lands between sierras, forested, rivers filled with cataracts.

(2) Little economic stone for savagery, or rather other useful substances easier to work more abundant; gems; vegetation immense; food mammals scarce; birds of plumage, fish, and marine invertebrates plentiful.

(3) Food partly natural, partly cultivated, cassava, fish, mollusks, turtles.

(4) Clothing little or none, bark cloth; decoration of the person with labrets, tattoo, and jewelry of teeth and other animal tissues.

(5) Immense huts and shelters, open below, thatched roofs, hammocks, central and individual fires.

(6) Polished stone, no chipping; pottery massive; diagonal weaving; shell heaps or sambaquis, agriculture.

(7) Weapons are rounded bows decorated with feathers and geometric seizing; arrows barbed with bone or bladed; clubs.

(8) Travel afoot; navigation of rivers difficult by reason of rapids; on the coast of Brazil canoes and house boats.

The central Brazilian area, the Matto Grosso, lying between the eastward sloping roof of Brazil and the Andean Atlantic slope, largely between the Araguay and the western boundary of Brazil. It is a most complicated area in its environmental resources, its stocks and tribes, and its arts. Its characteristics are:

(1) Hot climate, wet, alluvial, forested; rivers flowing into the Amazon and the Paraguay, abounding in cataracts.

(2) Materials of arts: Few minerals, replaced by bone, shell, and teeth; palm wood, hard woods, excellent reeds, gourds, cotton; fish, turtles, birds, monkeys.

(3) Dietary mixed vegetable and animal, cultivated and wild; manioc, yam, beans, fish.

(4) Dress, little; clouts, pretty feather ornaments, jewelry of teeth, masks, labrets, nose ornament; no tatoo.

(5) Houses open shelters with palm-leaf roofs; hammocks, open fires; gourd and pottery dishes.

(6) Tools of shell, teeth, bone; spindle, diagonal weaving, sand painting, cassava manufacture, agriculture; pottery quite suggestive of mound-builders' ware.

(7) Bows of Peru and of east Brazil and intermediary forms; arrows with bone and reed points; throwing sticks Australian type, clubs, axes.

(8) Barefoot travel, headband and carrying frame; canoes of a single piece of bark (wood skins) and dugouts.

South of the Matto Grosso, or mixed region, lies the Argentinian pampas, shading down to Patagonia. Differing much in features from place to place, the culture is not altogether to be dissociated from that farther north. The characteristics are:

(1) Monotonous plains, pampas, from high grassy chaco to the bleak wastes at the south.

(2) Only near the western border any stone for working; fish, guanaco, American ostrich (*Rhea darwinii*).

(3) Food consists of roots, fruit, aquatic products in some places, flesh of guanaco, and rhea; no husbandry; Paraguay tea.

(4) Dress scanty, guanaco robes, woven blankets; foot gear of peltry, hair side out.

(5) The house, or toldo, of the Patagonian is an awning of guanaco skin; fuel of grass, open roasting; skin beds; pappoose hammocks and frames, the first south of California.

(6) Arts are skin dressing, sewing with ostrich sinew thread, weaving, and hunting; no pottery; no chipped stone southward.

(7) The weapons were the spear, the lasso, and the bolas.

(8) Locomotion aboriginally altogether afoot; now on horseback.

The Fuegian culture area terminates the American Continent southward, and yet on this desolate point, 55 degrees south, Brinton finds three linguistic families. The characteristics are:

(1) Rocky islands with numerous inlets between dangerous headlands; cold and wet climate.

(2) The material resources are siliceous rocks, beech trees, rushes; land mammals scarce; marine fauna rich; dogs.

(3) The dietary is mollusks and fish largely, sea mammals, whales, fungi; cooking in hot ashes.

(4) Clothing scanty; a skin worn hanging on the neck as a wind break; paint and ornaments.

(5) Their houses are miserable huts of wattling covered with grass; no furniture; fire made with pyrites and carried about in canoes.

(6) Their arts are in wood, bark, bone, and textile; shell knife; no stone art.

(7) For weapons they use stones thrown from the hand, poor bows and arrows, barbed harpoons, slings, limpet sticks, nets; no fishhook.

(8) Little travel afoot; small canoe sled; large canoe of beech bark, made in three sections, to be easily taken apart in portages across headlands.

Table showing American environments in

Area and physiography.	Chief minerals, plants, and animals.	Alimentation.	Dress and adornment.
1. Arctic.			
Six months day; ice and snow; country low along the coast.	Soapstone, chert, slate, pectolite; stunted vegetation, drift; abundance of fish, birds, and mammals of sea and land.	Drink water only; eat fish, seal meat, whale, reindeer, raw and seethed.	Sleeved coats and hoods; skins of birds, seal, reindeer, and intestines; tattoo; labrets.
2. Athapascan.			
Yukon and Mackenzie drainage; lowland, subarctic fauna and flora.	Poor in industrial minerals; birch, conifers, poplars; caribou, bear, birds, fish, and fur animals.	Drink water; meat, fish of lakes, berries, and bark.	Tawed caribou skin, much adorned with quill work and beads; gaiter-like moccasins.
3. Algonquin—Iroquois.			
Subarctic to temperate; lowlands, prairies, and indented waterways and coasts.	Quartzite, sandstone, soapstone, diorite; hardwoods, birch, wild rice, tobacco; game, fish, mollusks.	Diet varied, meat, fish, marine invertebrates, wild grains and fruits, maize; granaries; tobacco.	Tawed-skin shirt, leggins, moccasins (low and adorned); tattoo and paint.
4. Southern United States.			
Rich river valleys and low mountains; abundant rain; Gulf Coast subtropical.	River gravels; stone, granular and siliceous in place; timber, cane, tobacco, maize; game, fish, and sea products.	Fish, meat, mollusks, maize, wild fruits abundant; granaries; tobacco.	Slight; deerskin robes, mantles of wild hemp; bodies painted; moccasins.
5. Plains of the West.			
Piedmont sloping to immense prairies of Mississippi Valley.	Few minerals; jasper, pipestone; apocynum, bois diarc; buffalo. overwhelmingly.	Meat; fish a little; wild fruits, pemmican, kinnikinic.	Skin clothing; low moccasins; feather and quill decorations; body paint and mutilations.
6. North Pacific.			
Moist, warm climate; archipelagoes and mountainous coast.	Slate, granular rock; immense forests of conifers; sea fauna inexhaustible.	Fish diet, mixed with berries; snuff and pipe.	Clothing of bark and hair, woven in twined pattern; tattooing of totems.
7. Vancouver to Columbia.			
Stern coast, prolific inland waters; rich lands coast to mountains.	Siliceous and granular rocks; textile plants and forest timber, edible roots; fish, waterfowl.	Fish diet, mixed with roots and berries; no agriculture; stone boiling in basket and pit roasting.	Skin and bark clothing; gaiter moccasins; head flattening.
8. Interior Basin.			
Partial desert among mountains.	Siliceous and stratified stone; few fish; deer and other game; timber poor; seed plants abundant.	Dietary meager; bread, mush, soups, meat; in some cases grubs and insects; hot stone and roasting.	Buckskin clothing, rabbit-skin robes; high moccasins; no painting or tattooing.

association with aboriginal industries.

House and house life.	Manufactures.	Hunting, fishing, war.	Locomotion and transportation.
Underground igloos of earth on timbers or whalebone; snow huts and summer tents; stone lamp stove, dishes of wood.	Chipping, sawing, grinding, carving stone and hard tissue; tailoring in skins; pottery a little in the west.	Harpoons, bird darts, fish darts, lance, fishhook, net, trap, bow compound and sinew-backed.	Fur boots, ice creeper, sled, dog, kaiak, umiak; snowshoes, rude.
Conical bark lodges; baskets, pots, and dishes of wood, bark, and basketry; stone boiling.	No pottery; coiled basketry; bark vessels, excellent skin dressing and working; curved knife.	Bow and arrow, lance, nets, hooks, traps, and pounds, abundant and varied.	Snowshoes, excellent; bark canoes, toboggans, dogs; much portage.
Conical and cylindrical lodges of skin or bark; barracks, shell heaps; central fire; roasting and boiling.	Chipped and polished stone; poor pottery; bark dugout and wicker vessels; mortar grinding; skin working; twined basketry.	Club, stone knife, lance, tomahawk, bow and arrow plain, barbed spear, pound, trap, weir.	On foot; in canoes and dugouts; snowshoes, dogs, and portages at the north.
Huts of cane, with mud chinking, grass lodges, earthworks, shell heaps; open fire, smoking, roasting, seething.	Chipping and polishing stone; gray pottery, stamped; diagonal weaving.	Bows and reed arrows, blow tubes, weirs, tomahawks.	On foot; dugout canoes; rafts of cane.
Skin lodges in circles; earth lodge; furniture and utensils, and fuel from the buffalo.	Stone chipping; pipe making; hammerstone, hafted; twined basketry; quill and hide work; little pottery.	Little fishing; plain, compound, and sinew-backed bow, short arrow, club, lance, tomahawk.	On foot and snowshoes; bull-boat; dog and horse for riding and packing.
Communal barracks; totem posts, central fires; furniture and utensils of stone and wood; stone boiling in dugouts.	Carved wood, slate, bone; twined, square, and diagonal weaving in wood, bark, and grass; no pottery.	Harpoons, floats, gigs, weirs; arts created by fishing; daggers, skin armor, slat armor, slave killer.	Dugout canoes altogether; little land travel except packing over the mountains.
Communal houses; furniture in greatly varied textiles; fire in pits.	Flinty and granular stonework; carving in soft and hard material; no pottery; basketry of five types.	Harpoon, club, fishhook, traps; daggers, bows and arrows.	Dugouts, bark boats, monitor shape; open-work snowshoes; packing over the mountains.
Shelters; live out of doors; stick beds; vessels of twined baskets, pitched; mush baskets; fire outside.	Chipping stone; no pottery; good skin workers; twined baskets for vessels; seed gathering, milling, and cooking.	Sinew-lined bow, plain arrow, short clubs; round shields.	No artificial travel; carrying in conical baskets with head-band.

Table showing American environments in

Area and physiography	Chief minerals, plants, and animals.	Alimentation.	Dress and adornment.
9. California and Oregon.			
Short valleys isolated enclosing rivers stocked with sea products.	No clay, siliceous and friable stone; fibrous plants, fruits, and woods abundant; fish, mollusks, and game.	Diet of fish, meat, acorns, pinyon; mush; stone boiling.	Buckskin and grass-fringed skirts, robes, and moccasins.
10. Pueblo region.			
Arid mesas and canyons among mountains; irrigable lands.	Shales, clays, gems; mesquite, yucca, agave, oak; deer, rabbit, antelope, coyote, puma.	Maize, pulse, melons, little meat; griddle and cooking pot.	Tawed skin and woven garments; formerly rabbit robes, feathers and paint; no tattooing.
11. Middle America.			
Mountains and tablelands, wet and dry season, isotherm 82° to 59° F.; vertical climate zones.	Friable stone, obsidian, jade-like stone, silver yucca, agave, cotton, maize, beans, peppers, fish, birds.	Maize ground, frijoles, griddle cooking; pulque, mescal, cacao, iguana.	Woven and bark garments, sandals of twine, hats, feather work, labrets.
12. Littoral and Insular Americas.			
Perpetual summer; no snow; mountains and insular areas in deep, clear seas; currents northwestward.	Granular stone, no chipping; shells, great canoe trees, cacao, manioc; no great mammals; fishes, birds, and mollusks.	Fish and mollusk, cacao, cassava, batatas, turtle, iguana, chicha, snuff.	Little clothing, bark cloth, feather work.
13. Cordilleras of South America.			
Elevated plateaus, with high mountains, gorges, desert coast, rainless, vertical climate zones.	Volcanic rocks, gold and silver; maize, potatoes, cotton, coca, cinchona, cochineal; llama.	Bread of maize, potatoes, fish, llama, guanaco, coca, chicha, salt.	Woven stuffs of cotton and wool; sandals, poncho.
14. Andean Atlantic Slope.			
Orinoco, Amazon, Maranyon, Madeira, Napo, etc.; tropical products; well watered and forested.	Minerals scarce; vegetation reeking; animal life arboreal and aquatic.	Fish, turtle, monkeys, peccary, manatee.	Bark cloth; feather ornaments, jewelry of teeth.
15. Eastern Brazil.			
Tropical; elevated tablelands between low sierras; forested; rivers full of cataracts.	Friable stone, clay; forests, palm trees, hardwoods; mollusks and fish.	Some maize and cassava, but chiefly on natural products of the soil; roasting and boiling.	Cotton, bark cloth, scanty clothing; labrets.

association with aboriginal industries—Continued.

House and house life.	Manufactures.	Hunting, fishing, war.	Locomotion and transportation.
Insignificant shelters, some under ground; no order in camps; shellheaps, granaries; fire in doors.	Excellent stone chipping; composite mortars; seven styles of basketry; twine. nets.	Sinew-lined bow and exquisite arrows, fish spears, slat armor, traps.	Poor boats, rafts; no snowshoes; conical carrying baskets with headband.
Under ground, crater, cave, cavate, cliff, mesa, and lowland pueblos; ladders; furniture and utensils of clay and textiles; ovens and open fire.	Polishing and boring stone: smooth, painted pottery; basketry five kinds, cloth; wall building; irrigation.	Bows and arrows rude; throwing clubs; nets for birds and rabbits; spears and axes.	On foot only; carrying with headband and toting with head-ring; sandals and moccasins.
Thatched and daubed hut, cut-stone buildings and temples, hammocks, granaries.	Stone hammering and chiseling, gem cutting, grotesque and painted pottery, paper, bark cloth; irrigation canals.	Atlatl and spear, bladed clubs, obsidian daggers, spears, slings; bows.	Dugouts, reed floats, professional carriers using headband and breastband, wearing sandals.
Thatched huts, often daubed or on posts; hammocks; no storage; chairs from single block.	No chipping; excellent carved and polished yokes, zemis, etc.; red pottery, stamped; shellwork and wood carving.	Clubs, throwing sticks, sharks' teeth, sword clubs, spears, tomahawk, or celt in pierced handle.	On foot; sandals of textile; dugout canoes; headband for carrying.
Fortified villages; thatched huts; bed on the ground; clay dishes; open fire; llama, dung fuel.	Hammered stone; huge buildings, little carved; metallurgy; pottery modeled; diagonal weaving, embroidery, quipu.	Sling, club with or without stone or metal head, saber of hard-wood.	Afoot; log and reed balsas; carrying on men and llamas; suspension bridges; couriers.
Wooden houses, thatched; sleeping bunks, couvade.	Work in wood with tools of teeth, bone, and shell.	Blowtube, poisoned arrows, square sectioned bow, dried heads, shields, trident lances, drum signals.	Afoot little; canoes of bark; headband in carrying.
Immense huts and shelters, hammocks, central fire, shell heaps.	Pottery, diagonal weaving, agriculture; on the waters extensive fishing.	Rounded bows, decorated; barbed and bladed arrows.	Travel afoot; canoes and house boats.

Table showing American environments in

Area and physiography	Chief minerals, plants, and animals.	Alimentation.	Dress and adornment.
16. Mato Grosso, Central South America.			
Hot, alluvial; upper waters in torrents.	Few minerals; bone and shell: palm, hard-wood, reed, gourd, cotton: turtles, plumage birds, monkeys.	Maize, cassava, yams, beans, turtle eggs, fish, smoking, roasting, cooking pot.	Little; pretty feathers and teeth: masks, nose ornaments: no bark cloth.
17. Argentina and Patagonia.			
Monotonous pampas, grassy plains to bleak wastes south; treeless.	Pampas grasses; huanaco; rhea.	Roots, some fish and sea products; flesh of ostrich and huanaco; open roasting with grass fuel.	Fur moccasins, huanaco robes, woven blankets.
18. Fuegian.			
Rock islands; precipitous; cold and wet; 55° south.	Siliceous stone; rushes, beech, marine fauna, birds, dogs; few mammals.	Sea animals, vertebrate and invertebrate; fungi; no storage; open fire.	Scanty; skin of seal, etc., for wind-break; paint and adornment.

association with aboriginal industries—Continued.

House and house life.	Manufactures.	Hunting, fishing, war.	Locomotion and transportation.
Open shelters, palm huts and roofs; hammocks; open fire, gourd and clay utensils.	Tools of shell, bone, and teeth, diagonal weaving; pottery, agriculture; graters; sand painting.	Mixed kinds of bow and arrow, throwing stick, clubs; ax; fish poison.	Barefooted; headband and frame for carrying; wood skins for boats.
Skin tolderias or awnings, open fire, grass fuel, cradle frames, skin beds.	No pottery, no stone working; weaving, skin dressing, ostrich-sinew thread.	Bolas; spear, hand noose.	Traveling afoot and on horse.
Miserable huts of wattling covered with grass; no furniture; fire made with pyrites.	Little stone art; bark, bone, textile work, shell knife.	Throwing stones, poor bows and arrows, slings, barbed harpoons, limpet stick, nets.	Section canoes of beech bark for portage; canoe sled.

THE COMPREHENSIVE ENVIRONMENT.

In closing, I desire to call your special attention to the ever increasing size and variety and comprehensiveness of the term environment as culture has advanced. At first, in what may be called the centrifugal condition of human evolution, the execution of limited environments went hand in hand with the production of races and varieties of peoples and languages and typical groups of industries. The overstepping of the boundaries of these in the course of time produced many changes of the profoundest significance in men and their activities.

First. The increase of knowledge was accompanied with the refinement, the intensifying, and the multiplication of desires and the means of gratifying them.

Second. These demanded longer journeys and the perfection of machinery; changes in commerce and the ministers of enjoyment.

Third. They demanded modification and increase of cooperative forces, of language, of law, of knowledge and intelligence.

Fourth. Growing by what it fed upon, these irresistible tendencies seized the whole earth, and henceforth it was one oikoumenē, one enclave, one environment.

ENVIRONMENT THE OCCASION NOT THE CAUSE OF INDUSTRIES.

From one point of view it would appear that all mankind and all arts are the outright product of this cunning environment. But a sober view, while it gives to the latter all deserved encomium beholds in the ingenious human creature the true source of all arts. I do not know a better proof of this than the fact that the withholding or the concealing of gifts by nature acts as a stimulus to ingenuity. Take, for example, the bow. There are regions where the wood for this implement is perfect, as in South America, or the hard-wood forests of Eastern United States. Here the very embarrassment of riches lead men to be satisfied with a very poorly made bow.

Now, the characteristics of a good bow are rigidity and elasticity. When our ingenious friend, the Indian, climbed the eastern slopes of the Rocky Mountains, away from the hard-wood forests, he invoked the mammals to yield the sinew from the leg or the scapula and with this he glues an elastic back upon his poor implement, or unites two or three horns so as to get his effect, the middle piece giving the columnar resistance, the wings putting to flight the arrow. By and by you approach the Hyperborean man, you ask him how he is going to have a bow. He tells you that he is in the current of progressive culture whose law is "the poorer the environment the greater the ingenuity." It is true that he has only brittle driftwood, that glue will not hold in his cold and damp clime, and that materials for arrows are scarce. The result of this is the sinew-backed bow and the harpoon arrow, together the most complicated and ingenious device ever contrived by savage mind.

The bow wood has one virtue, that of rigidity. By an ingenious wrapping of hundreds of feet of fine sinew thread or braid from end to end along the back with half hitches on the limbs, at every danger-point the virtue of elasticity is added and you have one of the most quickly responsive implements in the world. The arrow is quite as cleverly conceived, for it pierces its victim, acts as a drag or log to impede its progress and by its feather as a signal to the hunter in following his victim.

I am sure I should weary you if I should undertake to repeat this process of thought through the endless varieties of architecture, cooking, living, dressing, manufacturing, and going about. The story is the same. If men want houses, stoves, furniture, clothing, tools, power, or carriages or boats, they invent them, spite of environment, or rather by knowing and mastering the environment. As the size and shape of a cast is conditioned by the mold, not caused by it, industries are molded in the environment.

ALL ARE NOT IN THE CURRENTS OF CULTURE.

And now, in thanking you for your patience, let me say that in our comprehensive epoch, when all sunshine and all lands, and all winds, and all streams, and all terrestrial phenomena, and all history form the single and organized environment of every mind, it depends on each nation and each individual to say how much it or he will enter into the conscious occupation of this estate. Here in the nation's capital you may find men and women who can not read or perform any skilled labor whatever, who are the survivals of long past ages of ignorance and inexperience, who are only in the eddies of culture—in the zone of calms. Here also are the great minds of the world in touch with all culture. Between the two extremes are we, each and all, and I should be untrue to you if I did not implore each one before me to strive to be in the moving current as much as possible. We are the heirs of the ages and do not desire to be their prodigal son.

DUTIES OF THE FRIENDS OF TECHNOGRAPHIC SCIENCE.

When we turn our eyes toward that wonderful piece of architecture and sculpture called the earth, we need not ask in what laboratory it was executed. Time and Law were the workmen. The hills are almost as old as the earth, the streams of water are as old as the hills, the contours and coast lines are more ancient than man. All the forms of physiographic and vital existence are open for our study. The ground, the waters, and the air have been associated in the production of the earth as we now have it. More than all else the earth is the "heir of all the ages."

I need not tell a company of educated students that the living body of man is the inheritor of all general biological laws. To acquaint ourselves with these laws and to obey them is half the battle of life.

Now, few of us have learned this lesson and none of us profit by it. In that perfect day that is to come the heir of all the ages will look upon every indulgence that is fatal to life and to full intellectual activity as a sin and a crime against humanity akin to maiming and murder.

But there are higher laws of existence and the ages have richer treasures than gravity and physics and chemistry and biology.

A great philosopher of the past tells us that the spiritual life and the conquest of the earth are better than the ownership of the earth. This is what Tennyson meant by the ages of which you are the heir. The substitution of beast, water, steam, and electric power for mere bodily power; the substitution of mechanical devices and engineering for the hands and the arms of men; the development of literature, painting, lace work, engraving, sculpture, music, architecture, and landscape out of the natural sights and sounds of the world; the origination and perfecting of language; the gradual organization of the family, society, and government; the ever-improving explanation of the cosmos and ourselves called science and philosophy; the more ideal and less grossly material unfolding of the spirit world and the divine life within us are the inheritance of the present generation.

The heir of the ages is one who owns the ages. He is the master of the ages, not their slave. Their lands and resources, their powers and machines, their productions and commerce, their accumulations and enjoyments are his to control. The heir of the ages is a master spirit. He causes the fire to burn, he is not consumed by it; he causes the waters to flow, he is not overwhelmed by them; he passes through the deep, the deep can not enter him; he rides on the wings of the wind; he harnesses the lightning to his chariot. He is now the realization of the myth of Orpheus, at whose touch the rapid rivers indeed ceased to flow, the savage beasts of the forest forgot their wildness, and the mountains moved to listen to his song. All nature in his presence wore new charms. But the comparison does not stop there. This all-conquering son of Apollo, stricken for the loss of his sensuous Eurydice, pursued her to the under world. He was allowed to lead her thence on the promise that he would not look back. But when he turned to gaze on his lovely Eurydice she vanished forever from his sight. In unconsolable grief he gave himself to melancholy and was torn to pieces by drunken Thracian women. They threw him into the Hebrus, and it is said that its waters as they roll to the sea still whisper Eurydice, Eurydice! And thus the heir of all the ages, like a prodigal bird, perished in the electric light of his own passions.

There is a special sense in which this particular body of hearers are the heirs of all the ages. It is as the children and the heirs of science. Changing events and diversities of ambitions and interests will bring other men to our side and drive them away again. But the stamp of our intellectual kinship is upon us. Into our keeping must or ought to fall her interests and her good name. You should ever be foremost

in unselfish devotion, in zeal that looks for no recompense, in love that springs from intellectual maternity.

One by one or in groups the guardians of the past are surrendering their trusteeships. To-day it is a great secretary or a genius among discoverers who lays aside his pen; to-morrow it is a brilliant inventor or master mechanic; the next day it is a cunning hand that carries to the dark chamber its pencil or chisel which it can not will away; anon, a generous patron of science lives no more.

Now, who of all human beings should have a true and abiding interest in the preservation of these honored careers? Whose hearts should bleed when such men die? Whose hearts should be glad when they are honored, who in their unwritten wills gave and bequeathed to their children and heirs to have and to hold so long as they live and to hand down with accrued interest and betterments to their successors all true knowledge, all skill acquired with infinite pains, all the harvest of human industries that have been raised upon the generous and fertile environment called earth?

THE JAPANESE NATION—A TYPICAL PRODUCT OF ENVIRONMENT.[1]

By GARDINER G. HUBBARD.

Of all countries of the earth, none have made such wonderful and rapid progress in form of government and in the development of industries and commerce, and such great changes in its conditions of environment as Japan. This country, which twenty-five years ago was almost unknown, has come forward to take its place not only as the foremost of oriental powers, but in the sisterhood of nations. While we marvel at this wonderful change, a glance at her geographic position, her internal and industrial resources, a brief study of her past history, and of the character, manners, and customs of her people will help us to understand her present, and perhaps to foretell something of her future. Both the old and the recent development show Japan to be a typical product of environment.

In the geographic position of Japan and Great Britain there is a striking resemblance: both consist of a group of islands with extensive seacoasts, indented with numerous excellent harbors, and bathed by equatorial currents; their insular position protecting them from invasion by land, and offering every opportunity for commercial intercourse. Almost within sight of each lies a continent densely populated, affording a market for productions and manufactures; both are rich in mines of coal and iron ore. The mines of Great Britain built up and then stimulated her manufactures, and these developed commerce and banking facilities, and made England the first manufacturing, commercial, and financial power of the world. The mines of Japan are developing her manufactures and her commerce, and she must become the first commercial power of the Orient.

The Empire of Japan is composed of four large and three thousand small islands, forming an arc of a large circle, extending from the northeast, within a few miles of Kamchatka, southwest about 2,000 miles, and with Formosa, nearly 3,000 miles, from an arctic climate to one of perpetual spring and everlasting summer.

[1] Saturday lecture in Assembly Hall of the United States National Museum, May 9, 1896.

A long range of high mountains follows the general trend of the islands from northeast to southwest, culminating in the beautiful peak of Fujiama, 12,365 feet high. Volcanoes and earthquakes give to Japan its name of "Earthquake country." From the mountains clear and rapid streams make rich the valleys, while inland seas, dotted with small islands, beautiful bays, and numerous harbors, contribute to make Japan a nation of sailors, and to cover the waters with vessels and boats; the whole making a picture of surpassing beauty. The landscape is a continuous succession of lofty mountains and valleys, looking out on these inland seas, while the labor of centuries has brought the valleys and mountain slopes to a high state of cultivation.

Leaving the geography of Japan, let us glance a moment at its history and see how that has been affected by its geographical conditions and influenced by its environments.

The oldest existing race is the Ainos, who now live in the northeastern islands of the Empire, the coldest and least desirable portion. They originally occupied the greater portion of Japan, but were dispossessed of their lands; driven far north or enslaved, and so gradually intermingled with the subsequent immigrants, who were stronger races. These immigrants came from the islands of the Pacific, from China, Korea, and Mongolia. Into the southern portion of Japan came inhabitants of the Malay and Polynesian type; into the center came the Koreans and Chinese, while into the north came men of the Mongolian type.

The habitable portions of Japan are on or near the shore; this gives easy communication by water to all parts of Japan, and has led to the mingling of its races and the formation of the Japanese nation.

OLD JAPAN.

In former times the Mikado, as the earthly representative of the Deity, ruled with absolute power. But by degrees the Mikado and his court becoming weak and effeminate, the real power passed from the court and civil rulers to the army. The military officers gradually withdrew from court to fortified camps, and subsequently built castles, where they lived surrounded by their military retainers and dependents. They embodied in their customs and mode of life most of the features of the feudal system of Europe. Thus, in two widely separated portions of the world, each without knowledge of the other, similar environments produced like systems, and at about the same era. To the introduction of this system, unknown in any other part of Asia, Japan is greatly indebted for its subsequent development, for each castle became a center of civilization and of an independent growth. The military officers of the Mikado became Daimios, or territorial lords and barons, living in fortified castles scattered over the country. They usurped all the offices, compelled the people to become subject to them, and through the labor of these serfs acquired large hereditary revenues.

Subordinate to the Daimios were the Samauri, the military class employed by and dependent on the Daimios, living on their estates, faithful and loyal retainers. Under the Samauri were the working classes, serfs, little better than slaves.

Subsequently one of the Daimios usurped the civil power, nominally acting as the minister of the Mikado, calling himself the Shogun. Thus the Shogun acquired the temporal power and control of the army, leaving the Mikado, who had always been withdrawn from public sight, only the priestly office and the honor attached.

We have been in the habit of regarding Japan as a hermit nation, without any relation with the outside world. Fortunately, she has not been allowed to live permanently isolated from the rest of the world. Her conditions of environment have been largely influenced by three great waves of civilization which have swept over her. The first, from Asia, in the sixth century, brought Chinese literature and Buddhism. The second, in the sixteenth century, from Europe, brought the merchants of Portugal and Holland and the Jesuits from Spain. The last, in the nineteenth century, brought the civilization of America and Europe, with the Christian religion.

The effect of China on the art, religion, and literature of Japan we shall consider later.

The merchants of Europe had commercial relations with Japan for about seventy-five years, between 1550 and 1625. With the traders came the Jesuits, Xavier and his associates, who made many proselytes, probably six or seven hundred thousand. This contact with European civilization wrought important changes in Japan, though not perceptible to us.

During the last part of the sixteenth century persecution began, the Japanese asserting, and some believing, that the priests were endeavoring to overthrow the Government and to convert Japan into a papal province, and that Christianity tended to lessen reverence toward parents and ancestors, a prominent feature of the Japanese religion. This persecution continued until the middle of the seventeenth century, when the Christians had all either renounced their faith or had been put to death. We are told that the annals of the primitive church furnish no instances of greater heroism or constancy than those of the Christians of Japan.

This attempt to establish commercial relations with Europe and introduce Christianity resulted in the sealing of Japan against all communication with the outside world for two hundred years, in the expulsion of all foreigners, and in the prohibition of all intercourse between the natives and foreigners, save with the Dutch, at one point. It was made a capital offense to teach or preach the Christian faith, and Japanese were forbidden to leave Japan under pain of death and confiscation of their property.

Notwithstanding these laws and the feeling of the people, some light

from abroad continued to shine upon Japan. Shipwrecked crews were cast upon the shores; foreign ships were seen sailing past, and occasionally anchored in some port for water or repairs or trade. By slow degrees a few Japanese became desirous to see more of these foreigners, for although outside barbarians, they yet knew many things of which the Japanese were ignorant. These inquirers and seekers after knowledge belonged to the class of men we call radicals.

About the middle of this century, the Mikado, a man of greater ability than his predecessors, determined to recover the power formerly wrested from his ancestors, and on conference with some of the Daimios found they were dissatisfied with the Government of the Shogun and desired to restore the power to the Mikado, "for all men hated the Shogun while all men loved the Mikado." The radicals naturally joined the Mikado, thinking any change would give greater freedom and lead to intercourse with that other world of which they knew so little; others of a conservative temperament as naturally desired the reestablishment of the old system. Many were therefore united in opposition to the Shogun.

It was about this time, viz, 1853, that Matthew G. Perry, commander of a naval expedition of the United States, visited Japan and demanded the opening of certain ports to American commerce. After making known his mission he left, saying that he should return and then remain until the ports of Japan were opened. The next year he returned and renewed his demands with great tact and moderation. The Shogun, finding himself without support, was compelled to yield and sign the treaty. England and other European powers immediately followed the example of America, and compelled Japan to make treaties with them. The ports were opened in 1859 and 1860, but for several years there was very little trade; the lives, even, of foreigners were unsafe away from their flag. It was only by slow degrees that Western civilization was brought to Japan and the barriers to intercourse and progress removed. The Mikado slowly recovered his old powers, while the Shogun lost all his authority.

Then old Japan passed away; the physical environments remained, all others were changed. An experiment novel in history began. The closed country was opened; instead of the exclusion of foreigners, they were invited from all parts of the civilized world. Natives under the old régime had been forbidden to leave Japan under pain of death. Now, a commission of the highest nobles, with four cabinet ministers, was sent to the United States, Germany, England, and France, to study their systems of government, education, finance, justice, and religion, and the organization of their armies and navies. Japanese youths were sent abroad for education, and men of high reputation were brought from other countries as professors and teachers. The Japanese, though respecting themselves and their own civilization, realized that in many respects it differed from that of Western nations, and was capable of development.

Their financial and educational systems were modeled on those of the United States, Germany, and England; their judicial system was borrowed from the codes of half the nations of Europe; their navy upon the English; their army upon the German system.

In 1871, the Mikado became convinced that the overthrow of the feudal system was necessary, because opposed to modern life. He therefore issued an edict requiring the Daimios to surrender their territorial rights and revenues, to disband their retainers and dependents, and to retire to private life. They generally obeyed, removing from their castles to the large cities. For the privileges they surrendered they received an annuity equal to one-tenth of their old revenues, with relief from the maintenance of their dependents. An annuity was given to the Samauri, and freedom to the serfs.

Russia, Japan, and the United States each emancipated their slaves or serfs between 1861 and 1871. Russia emancipated about 49,000,000 serfs and sold to them the lands they had cultivated for their masters, for a fixed price, payable in annual installments, running through fifty years. Japan emancipated about 20,000,000 serfs and gave to them the land they had cultivated, subject only to the usual tax on real estate. The United States emancipated about 3,000,000 slaves without any provision for their benefit, save the enactment of laws—sometimes enforced. The former serfs of Japan are now its peasants and farmers.

In old Japan education was not common, though a considerable portion of the people could read and write. In 1872, the following edict was passed: "It is intended that education shall be diffused, and there shall not be a village with an ignorant family, nor a family with an ignorant member." Education is now compulsory. The chairs in many of the universities were at first filled by Americans and Englishmen; but as soon as the Japanese realized that they had secured from foreigners all that they could give, and that they could help themselves, without being dependent on foreigners, they dismissed them—not all at once, but gradually. This was carried so far that when the Japan-China war began there was not a single foreign officer in either army or navy.

Quite recently the Japanese converts have dismissed the professors in their theological seminary, asserting that the missionaries are unduly conservative, and not abreast of the best scholarship of America and Germany; while the Japanese scholars possess advantages in the study of theology, from their freedom from prejudices growing out of Christian tradition.

In 1876, Sunday was adopted as an official holiday, and all acts against Christians were repealed.

In 1877, an edict was issued forbidding the Samauri to wear the long and short swords which they had carried for generations—the first for combat, the second for "hara-kari." In no country has the sword been an object of such honor as in Japan, for it was a divine symbol, a knightly weapon, and a certificate of noble birth. It was the life

and soul of their order, yet on a single day it was finally and silently laid aside, and the old order passed away forever. The best skill of the artisan had been lavished on the manufacture and ornamentation of this weapon, at once the terror and safeguard of society. It is said that the politeness of the Japanese is largely due to the wearing of this weapon, for the sword once drawn could not be sheathed without the shedding of blood. When subsequently the law was repealed and the wearing of swords permitted, the Samauri did not resume them, for they had ceased to be a symbol of rank.

GOVERNMENT.

In 1889, the Emperor perceived that further changes in the Government were required, and in fulfillment of a promise made several years before gave a written constitution to his people, limiting his own powers and establishing a parliament, with a representative form of government. Parliament was inaugurated by a procession, in which the Emperor and Empress appeared together for the first time in public and as equals. Under the old régime, no subject saw the Mikado, except his wives and chief minister, for the people had been taught that no one could see the face of the Mikado and live, while the Queen was treated as his inferior.

The reorganization of the Government, the compensation to the Daimios and Samauri, and other expenses in making these changes, created a large debt, for which bonds were issued. Nearly all these were taken and held in Japan. The total amount of debt January 1, 1894, was $286,326,000, exclusive of war debt: interest, 5 per cent. The debt had been reduced $42,400,000 in eight years prior to 1894. The paper money, formerly at a heavy discount, has been greatly reduced, and is now redeemed at par in silver. The finances at the opening of the war were on a better basis than in most of the countries of Europe. Taxes, formerly unknown to the people, were imposed, and increased from time to time, by the Government. This occasioned much dissatisfaction, but when the war broke out opposition to the Government was changed to patriotic feeling, and all classes joined in support of the Emperor.

ROADS.

Another cause which has contributed very greatly to the making of Japan into a nation is its good roads, which have been for a long time better than in most other countries. One of the main roads of the Empire is called the Tokaido, or East Shore road, running from Kioto to Tokyo, about 300 miles. Along this road are fifty-six stations, or posthouses. All their large cities are connected by wide roads, with sidewalks and trees on either side, kept in repair by the General Government, with tea houses at convenient distances. Provincial roads connect the principal towns in each province, country roads the small towns; these are maintained, respectively, by the provinces and towns.

There are few horses in Japan, and all travel is either on foot or by conveyances carried or drawn by men. The norimon, or kaga, a kind of sedan chair, was formerly used, but the jinrikisha is now the common carriage—a conveyance introduced within the life of the present generation, said to be a development of a missionary baby carriage.

The first railroad was constructed in 1870; now between 2,000 and 3,000 miles are in operation. These are largely patronized, the travel increasing every year. Other roads are in process of construction. A few of the railroads were built by the Government, most of them by private companies at a small cost, as labor is cheap.

JAPANESE CUSTOMS.

It is impossible for the foreigner to understand the operation of the mind of the Japanese, and equally difficult for the Japanese to understand ours. Their environment, their lives, religion, customs, habits, thoughts, and opinions, inherited from generations, are not only unlike, but are generally opposed to ours. For instance, while we consider the relation of husband and wife as the most sacred, a Japanese, in common with the oriental world, is taught to regard the paternal relation as the most sacred. A Japanese who would leave father and mother for his wife would be looked upon as an outcast; therefore the Bible, teaching that "a man shall leave father and mother and cleave unto his wife," is regarded as irreligious and immoral. The family in Japan is not only the unit of social life, but the father as head of the family exercises supreme authority over the children and grandchildren. The doctrine of ancestral worship, prevalent in Japan and China, arose from reverence and obedience to the head of the family; but as it subjects the will to another it deprives the individual of personality.

WOMEN.

We are told that "the Japanese women are the crowning charm of Japan," and that the key to their life is obedience and subjection to the will of another. For generations the women have been taught that the three great religious duties of woman are obedience, as a daughter, to her father; as a wife, to her husband; as a widow, to her eldest son. The wife wears mourning when she leaves her parents to become the member of another family, while the absolute control of her life and will is transferred from her father to her husband.

The women are not as well educated as the men, yet in the literature of Japan there are many poems written by them. They mingle much more in social life than in any other Asiatic countries, and the Japanese girl is regarded by Asiatics much as the American girl is regarded by Europeans. Women are not secluded in harems, yet as in all oriental countries their lives are spent at home, withdrawn from associations outside the family circle. In the upper circles the man and wife neither take their meals nor appear together.

Instead of clubs, the Japanese frequent tea houses, where dancing girls and musicians, called "gaishas," are found, for relaxation, social intercourse, and amusement. These girls, associating with men and taught to interest and amuse them, become to a certain extent educated, acquire conversational ability, and often have more influence over the man than has the wife. That the development of a nation depends as much on the women as on the men is a principle not yet appreciated in Asia, and its recognition is one of the great blessings that Japan will acquire from Europe.

JAPANESE DRESS.

A few years ago many Japanese substituted the European dress for the oriental as an evidence of civilization, but they soon realized that it was unsuited to Japanese life and that its adoption would lead to the introduction of Western domestic customs and the abandonment of their ancestral habits; a reaction followed, and they generally decided to retain their own dress. In the army, navy, police, and in business houses fashioned on foreign models, the European dress has been adopted as most convenient. Although required in court circles, some officials who are compelled to wear the European dress take it off as soon as they return home. One very wealthy nobleman occupies a double house—one half his Japanese home, in which he lives: the other half furnished in the French style, where he receives foreign visitors and officers of the court. The kimono, a long dress open in front, fastened around the waist by a girdle, is the principal garment of both sexes, and is better fitted for sedentary than active life.

If Japanese women take the position that women hold with us, they must change their dress to suit their new occupations. This will require them to give up their quiet life and live among men, and not, as now, at home. We trust they will retain their exquisite taste in the beautiful designs and colors of their silk and cotton textures even if they change the fashion of their dress.

BUILDINGS.

The Japanese houses usually receive light and air not from the street, but from small courts or gardens in the rear. The entire side of the house on the garden is movable, so that the interior can be thrown open to the day and sun light. The houses generally have overhanging roofs, which are either shingled, tiled, or thatched. The floor is raised from 18 inches to 2 feet above the ground, and the space between the floor and ground is generally left open for the air to blow through. The houses are usually small and low, from 6 to 8 feet in height; the partitions are wooden panels 3 feet wide, sliding in grooves in the floor and ceiling, and covered with paper. Neither paint, varnish, oil, nor finish is used about the house. Instead of windows they have screens covered with thin white paper, protected on the outside by sliding shutters. As the people

sit upon the floor, they have no need of furniture. For seats they have mats, all of the same size and alike. The size of the room is known by the number of mats on the floor. Upon these mats the people eat, sleep, and die. They are bed, chair, lounge, and table combined. Their meals are served in lacquer dishes on the floor. The mats at night are covered with wadded quilts, put away in the daytime, and on these they sleep. The houses are without fireplaces, chimneys, or smoke, being heated by braziers of charcoal. Every house contains one or more vases, and often hanging baskets filled with flowers arranged with greater taste than with us, while the paper upon the panels forming the partitions is ornamented with drawings and pictures more beautiful than those we find in our homes. Fireproof buildings are attached to many of the large houses, into which furniture and valuables can be moved in case of fire. Some writers criticise the houses of the Japanese because they are built of such frail materials and so loosely put together, forgetting that these typical Japanese houses, though entirely unsuited to our life, are better fitted for earthquake-shaken Japan than buildings of wood and stone. A few hundred dollars will buy and furnish a good and commodious house. Mr. Morse tells us that his house in Tokyo was 21 by 31 feet, with an annex 15 by 24 feet, with vestibule, hall, and kitchen—seven rooms and nine closets. The cost of the house was about $1,000, on a lot one-quarter of an acre in extent which cost $330; annual tax, $5.

Public baths are universal, and for a cent or two one may have a hot bath, while for the house they have bath tubs made with ovens for heating water. That the Japanese are a most cleanly race is apparent in their houses, their workshops, and in the care with which they look after everything in their charge.

Western architecture has been adopted for buildings in which Western occupations are carried on—as the post-offices, custom-houses, breweries, and cotton mills—but even in these buildings they have often developed purely oriental features.

LANGUAGE AND LITERATURE.

The Japanese language is a combination of the tongues of the ancient inhabitants of the islands, and is therefore unlike other languages. Literature was introduced into Japan from China with the religion of Buddha; but the words and the pronunciation have been so softened to fit the melodious Japanese tongue that a Japanese can not understand a Chinese nor a Chinese a Japanese. As a large proportion of the Chinese characters are used, it is not difficult for a Chinese and Japanese to communicate by writing.

The difficulty of learning to write the Japanese language is very great, as in addition to the Japanese alphabet some 15,000 to 20,000 Chinese characters must be memorized and the eye and hand trained to distinguish and delineate them. It is said that it requires seven

years for a boy to become sufficiently familiar with the Chinese characters to use them readily; thus the time given to real intellectual training is greatly lessened.

An American started the first newspaper in 1871 with 1,200 characters, but was compelled to increase them, and now uses 12,000. In the printing office each compositor sits at the desk with the letters of the Japanese alphabet within his reach, while boys bring the Chinese characters from their numerous places for him to set up.

The Japanese literature is rich in works of fiction, fables, legends, and poetry. Many of the legends are very beautiful, full of poetic feeling and fancy, and as they are generally written in Japanese are largely read by the common people.

As science and arts are unknown to the Asiatics, their language is insufficient for the requirements of the highest intellectual and scientific culture.

RELIGION.

The earliest religion of every savage tribe is the expression of fear and dread of the unknown and a desire to propitiate the mysteries, both evil and good, and is always largely affected by the environment. In Japan earthquakes average two a month, and one hundred in one revolution of the moon are not uncommon. Almost every mountain top is or has been a crater from which the molten lava has flowed down, destroying many a village and town. Floods of rain on the mountains often cause great landslides and inundations, destroying towns and cities, while once or twice a year the typhoon, most dreadful in its ravages, must be expected. These all affect the mind and influence the religious feeling. The God of Thunder, of the Earthquake, and the Dragon all men worshiped. The earthly representative of the Deity was the Mikado, whom all men reverenced, feared, and obeyed. In the family ancestral worship—reverence and obedience of the child to the father during his lifetime—was taught. This principle has been unfavorable to the development of the race, as it involves the sacrifice of independence, free will, and personality.

The mythology of Japan abounds with beautiful, romantic, and weird stories, the foundation of much of its art and poetry. As the intellectual progress of the people, their art and literature were developed, the need of a religion higher and more spiritual than Shintoism—as their old religion was called—was felt. This was found in Buddhism, which came from China in the sixth century. It taught patience, courage, charity, the subjugation of the animal nature and passions, the purification and elevation of the moral nature in the struggle for higher life. It regarded the present as only the highest of a series of transformations through which the soul must pass to reach Nirvana, the eternal peace; but if the discipline of this life should be ineffectual to elevate the man, the soul must return to a lower animal life, once more to pass by ascending incarnations to its final absorption in Buddha.

The influence of this religion was not confined to the daily life, but acted upon the literature and art.

For a time it seemed as if Buddhism would supplant Shintoism and become the religion of Japan, but instead of that it elevated and spiritualized Shintoism, so that it regained much of its hold upon the people. The priesthood is not a caste, nor is the whole life of the priest devoted to religious observances. In the Shinto temple neither idols, images, nor pictures are found: only the altar on which are laid offerings of fish and fruit. At different times eminent men in each of these religions have formed sects, with many followers.

Christianity has made many converts in Japan since the ports were opened, whose numbers are steadily increasing, but Buddhism is still their religion.

ART.

The art of the Japanese differs from that of the Aryan or Indo-European, for it is not as with them the grafting of one style upon another, but the accumulated knowledge of many centuries, unaffected by foreign influences. Within its confined scope it was in advance of the art of other nations when the country was opened to foreigners. For her art as well as her literature, Japan is undoubtedly indebted to China and Korea, as among the most skillful workmen of the famous Satsuma faience are the descendants of Korean artists. After the introduction of art its development was greatly promoted through the influence of the feudal system. The Daimios required swords and armor, and their retainers were employed in their fabrication. Whatever time or labor was required to produce the finest and most beautiful article was freely given, and thus skillful artists were trained first in the fabrication of swords, and then in works of art. There was great rivalry among the Daimios and these artists to produce the most beautiful works, and this rivalry was further stimulated by the custom of sending beautiful presents from one lord to another.

Pictorial art has never attained any great importance, but the decorative and industrial art of Japan is original, and excites the admiration of the world. The children early use the brush in making the many lines and curves required to form the complicated Chinese characters, and thus acquire that accuracy of eye and skill of hand necessary for artistic work. They have no knowledge of the architecture or art of Egypt, Babylon, and Greece, on which that of Europe and America is founded. They know little of either sculpture or music in their highest development, and their delineations of the human form, although showing skill, are only bizarre and grotesque: but they have the closest and most sympathetic appreciation of nature in her most delicate and beautiful aspects, and their exquisite representations of the varied forms of animal, insect, and plant life make their work the wonder and envy of our Western artists.

In porcelain, pottery, and lacquered ware and in metals and bronzes

the Japanese have never been surpassed. Their swords were almost miracles of beauty and skilled workmanship, and there was a great demand for them, as every Samauri wore two swords.

The art treasures of Japan were first brought to our notice at the expositions of London and Paris in 1862 and 1867, of Vienna in 1873, and of Philadelphia in 1876. And it was the opinion of experts, "that for beauty, grace, and perfection of workmanship, variety of form, and novelty of design, they competed successfully in Paris with the best products of Parisian ateliers, in Vienna, with Viennese specialties, and in Berlin with the celebrated iron and bronze work of that capital," while they could be sold at a price below that of European articles of similar kind.

But the environment was changed; different and newer work especially designed for the European market called for and produced in great quantities and this new demand, unfortunately, does not require the taste, beauty, and delicacy which characterized the early productions.

There is no better illustration of the modification in Japanese decorative art resulting from outside influence than in the pottery known commercially by the name "Satsuma." The Satsuma potteries have been in operation for many centuries, and their products are highly prized by the Japanese. The true Satsuma ware, such as is found in the cabinets of Japanese collectors, is always small, of graceful form, with simple decorations of flowers and birds so disposed as not to cover up the delicate crackled glaze which they greatly admire. The Satsuma ware most highly prized by many European and American collectors is quite different, being usually in the form of large plaques or vases, covered with elaborate, theatrical paintings of men and women, in brilliant costumes, absolutely obscuring the color and texture of the ware. Nor is it a product entirely of Satsuma, the decoration being applied in Tokyo and elsewhere.

With the increase of the demand, the individual workman is giving place to men and women crowded together in factories using machinery, where the personality of the workman disappears.

In considering the art of Japan and the great progress made in this and other departments, we must bear in mind that this development has been on lines in which the Japanese had formerly been distinguished, for they have accomplished little in any of the arts and sciences introduced from Europe, excepting such as could be done by imitation. Painting, music, architecture, and sculpture require time and the cultivation of the mind and taste.

ARMY.

The Japanese have always been a warlike people. Twenty-five years ago Japanese soldiers were armed with bows and arrows, with a few great, heavy, unwieldy muskets of the time of the Armada, wore huge

grotesque masked helmets to frighten the enemy, with chain and lacquered armor for defense and protection, and were commanded by a man with a fan. In 1871, their old arms were thrown aside; experienced officers from France and Germany organized a new army, with continental conscription and regular training. The transformation was rapidly carried out without diminishing the warlike spirit of the Japanese. In January, 1893, before the Japan-China war broke out, Japan had an army which, though small, would not have done discredit to any of the nations of Europe in organization, discipline, and equipment. Its actual fighting strength was between 60,000 and 70,000 men, with power to call a much larger reserve force into the field. The Japanese had then neither great machine shops nor facilities for building ships, nor for the manufacture of large cannon, but they acquired from Europe armaments, ships, cannon, and equipment for their army.

NAVY.

The position of Japan, with its inland seas and good harbors, early led them to become good sailors. The vessels of old Japan have been replaced by a large fleet of sailing vessels and steamers.

In the recent war between Japan and China, the two countries present strong contrasts. Its opening found Japan fully prepared, all plans for the campaign rapidly made: China, without any plans. The navy of each nation composed of the best modern ships and guns built in Europe: the Japanese fully equipped and manned by their own officers, the Chinese officers generally aided by Europeans. The fleets of China now either lie at the bottom of the ocean or fly the flag of Japan, enrolled in its navy. The campaign was as well planned and carried out by Japan as the campaign of Germany against France in 1870. The war was the contest of civilization against barbarism, of intelligence with ignorance.

The ports of China were opened to foreign commerce before those of Japan, and China had for a long time more intercourse and larger commercial relations with Europe than Japan. But China represents ancient conservatism, neither change nor progress, stagnation without life. What China was three thousand years ago that she is to-day, while Japan represents entirely new conditions of environment, followed by the most rapid and striking development the world has ever witnessed.

Japan is not only the foremost nation of the East, but her civilization compares in many ways favorably with that of Europe.

INDUSTRIAL ERA.

The natives of Asia, unlike those of Africa and America, have always been industrious, economical, and hard workers. They have not, therefore, to learn the hardest of lessons—to work—but only to apply their work in new directions.

Although the ports of Japan were nominally opened in 1854, it was not until the appointment of Commissioner Harris, in 1860, that any trade was carried on. From a very small beginning it slowly but steadily increased each year more and more rapidly. At first all kinds of foreign goods were bought and found a ready market; the imports largely exceeded the exports, and the balance was paid in gold and silver, the accumulation of centuries.

Then came hard times for Japan; imports fell off, for the people had no means to pay for them. Next came the great expositions in Europe and America and a demand for the products of Japan—their tea, silk, and art works—so great that the balance of trade turned in their favor. A good market for cotton goods among the Japanese was created, and to supply this demand the manufacture of cotton yarn into cloth was commenced, and then as the demand increased, factories were started with machinery imported from the United States. Then cotton was imported, more factories built, the machinery copied and made by the Japanese. Now Japan is exporting cotton goods to India and China in competition with England, and will soon supply the market of the nations on the Indian and Pacific oceans.

Until 1860, all commerce between Japanese ports were in Japanese junks and boats, then English and American steamboats took their place for a few years, only to be supplanted by Japanese steamships, and now one of the Japanese steamship companies is among the largest in the world. They are now sailing to the islands of Australasia and India; soon the Japanese flag will be seen at Tacoma and San Francisco, and will ere long drive out English and American vessels from the carrying trade of the Pacific for the same reasons that they have driven their vessels from the Japanese waters.[1]

The opening of the ports was followed by the establishment of foreign banking, mercantile, and trading houses. Their number rapidly increased, and the trade, both wholesale and retail, was carried on by foreigners, and all suits between foreigners and natives were tried by foreign consuls. Gradually Japanese retail shops were opened in the ports, then wholesale warehouses and banking houses were started, and treaties made by which Japanese tribunals were substituted for foreign courts. Soon all this foreign trade must pass into Japanese control.

When we see what one generation has accomplished, and remember that those whose fathers knew nothing about cotton or cotton goods, nothing of machinery or manufactures, are becoming large manufacturers and supplying Asia, we begin to realize the magnitude of the change, and wonder what will be the ultimate result of these new conditions of environment to Japan and the world. The preparation began on a small scale some years ago has been steadily carried on. The

[1] Since the above was written, a contract has been made for a line of Japanese steamers to ply between the ports of Japan and Seattle in connection with our northern railroads.

rapid mountain torrents with their falls furnish water for electric power, her numerous and extensive coal fields steam power for the manufacture of the products of her mines and forests. Wages are low, for the people live on easily obtained rice and fish, in houses cheaply built, with low rents. Only 20 to 30 cents a day is paid for work that commands ten times as much in Europe and America, while the quick intelligence of her people give Japan facilities for rapidly becoming a manufacturing nation. A recent traveler says, "You can not suggest to me one article that I can not export in six months from Japan, and, regardless of our tariff laws, undersell the market in the United States."

They are the French of the East; their artistic instincts and their ingenuity in the use of machinery make them the competitors of Europe, particularly in specialties. Their profits are so large that their industries will increase with greater rapidity every year.

Japan as a nation possesses an individuality stronger than our own. Our power of cooperation and organization of men and capital into corporations gives to us a certain advantage, but even this corporate organization they are rapidly acquiring.

The wages of labor in Japan must necessarily increase, but not in one generation, scarcely in two generations, can all their habits of life, their dress, food, and homes change so greatly as to increase the price of labor more than 100 or 200 per cent. Yet at this increase wages in Japan would be very much lower than in Europe or America.

Our brief sketch shows somewhat of the changes which new conditions of environment have worked out within twenty-five years. The hermit nation has come into communication with the great powers of the world; her embassies are found in the capitals of Europe and America; she holds her position with dignity and self-respect. Her present position is honorable, the presage of a brilliant future.

Japan is indeed a typical product of environment. A warm climate, where the land and water not only contribute food, but induce continued intercourse and the welding of different races into one nation.

From the contact of man with man, from city life, not from country, comes the highest civilization. In Japan this contact has been maintained for centuries and has led to the steady development of her people. Volcanoes, earthquakes, mountain torrents, and typhoons have affected not only the land, but the character, religion, and art of its inhabitants, while its development has been hastened by the opening of the ports, the introduction of Western civilization, and the demand for her products in every market of the world.

THE TUSAYAN RITUAL: A STUDY OF THE INFLUENCE OF ENVIRONMENT ON ABORIGINAL CULTS.[1]

By J. Walter Fewkes.

The science called ethnology claims as its field of research the study of all racial characteristics of man. It deals not only with his physical features, social grouping, and geographical distribution, but also with the products of his hand and mind, his thoughts and feelings. No race or individual is so low in the scale of being as to be utterly devoid of some idea of the supernatural, and as this is a universal human characteristic it is naturally one of the subjects which presents itself for study by the ethnologist. The study of the evolution of supernatural ideas, like that of all other human characters, ought not to be limited to a few favored races, nor should the term "religion," in its scientific use, be restricted to any group or race of man. It must be broad enough to embrace the supernatural conceptions of all men, low and high in the scale. No poor or insignificant grouping of men and women should be regarded too wretched to be studied, and the scientific man can not overlook any if he is loyal to scientific methods. A generalization which is built on limited knowledge of the religious characteristics of a few men or those of gifted races will as surely fail as a general law of linguistics based on the language of any one of the great races to the neglect of others. There was a time when naturalists overlooked the lowest animals in their studies of the evolution of organic life, but now it is universally recognized by biologists that we must look to the most inferior animals for a solution of many problems connected with the highest. In studies of the development of the supernatural in the mind of man the same thing is true. The laws of the evolution of religious thought can not be scientifically studied if the culture of primitive man is neglected. Unless I am greatly mistaken, the roots of some of the purest spiritual conceptions reach far down into savage and barbarous stages of culture.

We are accustomed to designate the crude supernatural ideas of savage and barbarous peoples as cults, and every cult will be found on examination to be composed of two complemental parts, known as

[1] Saturday lecture in the Assembly Hall of the United States National Museum, May 16, 1896.

mythology and ritual. Around the former group themselves the various beliefs regarding the supernatural, and about the latter the processes by which man approaches and influences these supernal conceptions. This bifid strand runs through all supernatural ideas, from those of the savage to the civilized man. As nature has thus united them, they must always be considered together in scientific studies. We have seen in one of the previous lectures of this course how certain arts of man are affected by environment. I shall endeavor to show a connection between ceremonial practices and climatic conditions, which are, I take it, essential factors of environment. For an illustration, I have chosen the influence of an arid climate upon the ritual of one cluster of American Indians.

There are certain common components of all cults which are as widely spread as the races of man and exist independently of surroundings, while there are others which are profoundly affected by environment. Our subject especially deals with the latter, and as the ritual is capable of more exact scientific analysis, I have in mind to discuss the modifications in it which can be traced to purely climatic causes.

To simplify the elements of the problem we must chose not only a primitive form of ritual, but also as far as possible one which has been but slightly modified by the introduction of foreign influences, and hence other environments. We must avoid as much as possible complexity due to composition. It is a very difficult task to determine the aboriginal cults of any primitive people, for modifications resulting from contact with other races are present almost everywhere we turn.

Every cluster or grouping of men known to me is composite in its character. Yet the task is not wholly hopeless or beyond our powers. The work before the American student is facilitated by the fact that we have still living in our country surviving members of the American race who, on account of isolation, have been slightly modified by foreign influences. I wish this afternoon to call your attention to one of these, and to discuss the influences which evironment has exerted on their ritual.

The people concerning whom I shall speak are commonly called the Mokis, although they prefer to be known as the Hopi. They live in a region of Arizona, which from its discovery in the middle of the sixteenth century, has been designated Tusayan. The Hopi or Tusayan Indians belong to the so-called village or pueblo people—the peculiar culture of prehistoric Arizona, New Mexico, Colorado, and Utah. While what I shall say especially concerns one group, it may in a general way be applied to the culture of a wide territory called the pueblo area of the southwestern part of the United States. In a natural sequence a discussion of the effect of environment would follow a statement of the distinctive characters of the physical features which characterize surroundings; and in order that you may have an idea of the climatic conditions of Tusayan, let us take a few moments to

consider these peculiarities of the environment. In physical features this province is a part of the great arid zone of the Rocky Mountains, to which in former times was given the name of Great American Desert. It lies in the northeastern part of Arizona, about 90 miles from the nearest village of white men on the south and about the same distance east of the Grand Canyon of the Colorado. On all sides it is isolated by dry deserts, a dreary extent of mountains, mesas, and arid plains about 6,000 feet above the level of the sea. No permanent streams of water refresh these parched canyons or fields, and the surroundings of this isolated tribe, organic and inorganic, belong to those characteristic of desert environment. The rains are limited in quantity—liable to fail at planting times, although later in the summer pouring down in copious torrents, that fill the depression by which the water is rapidly carried away from the thirsty fields. Springs of permanent water are small and weak, and when abundant, poor and hardly potable. In this unpromising land a few less than 2,000 Indians strive to maintain themselves by agriculture from a barren sandy soil which a white farmer would despise.

Nor is the unremunerative soil the only hostile environment with which this industrious race of aboriginal farmers has had to contend. Incoming marauders, in the form of nomadic enemies, have from prehistoric times harassed them, preyed on their farms, and forced them to adopt inaccessible mesa tops, high above their fields, for protection. Perched on these rocky eminences they have erected seven stone villages in so clever a way that they seem to be a part of the cliffs. Animals in desert surroundings as a protective device have taken on the color of the soil, but these men have built their towns in the cliffs so deftly that they seem to be parts of the mesas themselves. They have succeeded well in this protective device, due to environment, for at a distance the pueblos are indistinguishable from the cliffs on which they stand.

I need not dwell on the forbidding aspect of the mesa tops on which these villages are built. Not a sprig of verdure, drop of water, or fragment of fuel is to be found upon them. If there is one physical feature which may be said to characterize Tusayan, it is the paucity of water, or rather its unequal distribution in different seasons of the year.

The character of animal life is also significant, for it is of such a nature as to exert a profound influence. A race dependent on animal food alone would have starved for game. The great ruminants, as the bison, which more than any other animal influenced the culture of the Indians of the great plains of the Mississippi, never visited this region. No domesticated animals made pastoral culture possible. There were small rodents, many rabbits and hares, and a scanty supply of antelope in distant mountains. Unpromising as was the soil for agriculture, the resources of the hunter were much less, and in this region man was forced to become an agriculturist.

It is, therefore, clear that the sedentary agricultural life of the Tusayan Indian is the direct result of organic and inorganic surroundings. Forced from some reason unknown to me to live in a land where animals were so few that he could not subsist from the products of the chase, he found a possible food supply in plant life, and he accepted the inevitable. He adopted the life which environment dictated,[1] and accepting things as they were, worked out his culture on the only possible lines of development. He raised crops of maize, melons, and beans, cultivated and harvested various grains, but at times when other things failed found food in cacti and the meal of piñon nuts. Accepting the inevitable, man's ritual became a mirror of that part of his environment which most intimately affected his necessities. The irregularity of the rains, and the possibility that the corn may not grow, developed the ritual in the direction indicated. As long as the processes of nature go on without change, no special rain or growth ceremonials would develop. In a bountiful soil which never fails the farmer, where the seed dropped in the ground is sure to germinate, and the rains are constant, no ritual would originate to bring about what was sure to come. But let natural processes be capricious, awake in a primitive mind the fear that these processes may not recur, let him become conscious that the rains may not come, and he evolves a ritual to prevent its failure. He is absolutely driven to devise ceremonials by which to affect those supernatural beings whom he believes cause the rain and the growth of his crops. The cults of a primitive people are products of their necessities, and they become complicated as the probability of their needs not being met are uncertain. The two needs which sorely pressed the Hopi farmer were rain to water his crops and the growth and maturity of his corn. My problem, therefore, is to show by illustrations that the two components, rain making and growth ceremonials, characterize the Tusayan ritual, as aridity is the epitome of the distinctive climatic features of the region in which it has been developed.

There are, as before stated, certain elemental components of all cults which are as widespread as man, and apparently exist independently of climatic conditions. These elements are psychical, subjective, and occur wherever man lives in deserts, islands, forests, plains, under every degree of latitude and temperature. A more profound philosophical analysis than I can make may resolve even these into effects of environment, but their universality would seem to show that they are not due to the special climatic condition of aridity characteristic of Tusayan. I do not regard it pertinent to my discussion to attempt to explain their origin, but we can better appreciate the Tusayan ritual.

The genus *Homo*, emerging from genera of animals, most of which

[1]For a discussion of the relations between highest stages of culture in aboriginal America and arid climate, see my article on Summer Ceremonials at Zuñi and Moqui Pueblos, Bulletin Essex Institute, Vol. XXII, Nos. 7, 8, 9. Salem, Mass.

were timorous and bodily weak, inherited from them a wonder and fear at anything unusual or uncanny. This dawning intelligence, influenced by such sentiments as wonder, fear, hope, and love, reached that mental condition when, as pointed out by King, it ascribed all happenings about itself to luck.[1] His heritage was a mind unable to separate the normal from the abnormal, and everything to such a mind is mysterious, and all nature is regarded as living, but we can hardly suppose that in that condition it deified or saw gods in everything. Man understood the causes of few of the mysteries about him, and felt himself at the caprice of chance. He was a consistent fatalist, overlooking good, for that was normal, but associating the bad with chance. In this early condition a stage of supernaturalism called fetishism, or the use of charms, spells, amulets, mascots of various kinds to control chance, arose. As far as I know, no race has wholly outgrown this condition, and the lower we descend in the scale of humanity, either historically in our own race, or ethnographically among savages, the relative predominance of fetishism increases. There is no more constant element, none following the same law of increase; the present forms of monotheism have the least, the lowest savage the most. While at present there survives no people so degraded that fetishism is the only cult, those nearest that stage are the lowest in mental, moral, and social attainments. I need not remind you that at that early stage a fetish was not an idol, it may or may not have had a regular form; a stone, a root, an amulet may serve as a fetish. In this stage of development every individual came to believe that he had a certain protective charm. We can hardly believe he had a system of gods or that he recognized such. Later in its evolution fetishism became incorporated with other higher elements, especially symbolism, but in its archaic conception this was impossible.

The highest outgrowth of pure fetishism was the shaman or medicine man. It was recognized that certain men were gifted with occult powers beyond their fellows, and were more potent to control happenings. But this medicine man made use of impersonal amulets, not personal spirits.

The second stage in the growth of the supernatural was a belief in a spirit[2] or double of man, the concept of animism. When through

[1] I find myself in accord with Mr. J. H. King, who has discussed this subject at length in his work, The Supernatural; its Origin, Nature, and Evolution. While there are several points in his discussion where I can not see my way clear to accept his interpretations, I have in others found my views almost coinciding with his. He has discussed the subject in so schelarly a manner that the small space I can give to this great subject might have been better occupied with quotations from his volumes. His work should be thoughtfully studied by everyone interested in this subject.

[2] The recognition of spirit was of very early date, and is regarded by Sir J. Lubbock, Dr. Tylor, and Herbert Spencer as characteristic of all supernaturalism. Mr. King, however, seems to me to have advanced strong reasons to show that fetishism may have antedated animism. Although I have adopted his view, I am sure there is much to be said on the other side.

dreams and other psychical phenomena man recognized his soul, he immediately extended his concept to animals, plants, stones, all things, and thus everything was thought to have an intangible double, soul. Man sought to ally himself with some one of these souls; if a hunter, some animal spirit, for instance, as an aid. This became his totem, and everything came to be a totem of power depending on needs of man. As fetishism was the archaic condition in the groping of the human mind, totemism was the following, and both evolved together, mutually reacting on each other and interdigitating in their development.

As the inevitable outgrowth of animism and its twin brother totemism came ancestor worship. Totemism and animism are sometimes limited to animal worship, from the fact that zoomorphic totems naturally were chosen by hunters, but especially among agricultural people totems of corn, rain, and the like replaced zoomorphic forms. The forces of nature thus became totems—sun, moon, earth—some with animal, others with human personalities. A totem of a family became a tutelary god, and groups of tutelary gods with a regal head became a council of gods as among the old Greeks.

Political and religious conceptions kept pace, a patriarchal head of the family was reflected in the mythology. A king suggested a monotheism. Isolated phratries living in groups like the prehistoric pueblos recognized no supreme political chief; their system was feudal; they were too low for monotheism. I believe there is no good evidence to prove that they ever advanced higher in the evolution of mythology than a form of totemism, in which powers of nature under anthropomorphic or animal disguises were worshiped.

I have said that the ritual of man can not be separated from his beliefs; it is incomprehensible alone. Let us, therefore, glance at the mythology of the Tusayan Indians. These people had never, when unmodified by European influences, advanced higher than the worship of anthropomorphic powers of nature, although all lower forms of worship, as of animals, ancestors, and fetishism, were prevalent. As far as I have studied the beliefs of the Tusayan Indians, I find no evidence that they recognized monotheism or the existence of a Great Spirit, creator of all things. With them as elsewhere among American Indians whenever we find a knowledge of a Great Spirit we see, as pointed out by Mr. R. Dorman,[1] "Nothing more than a figure of European origin reflected and transformed almost beyond recognition in the mirror of the Indian mind." It is suggestive that the Indian knows only the name, he has no stories pertaining to him, but when you inquire about creation you elicit myths of the works of a spider woman or the birth of men from the caverns of the earth. A conception of a Great Spirit, wherever reported from savage people of North America, is the work of missionaries, soldiers, or traders.[2]

[1] Anthropological Institute, Journal, Vol. XI, page 361.

[2] Considerable evidence has been adduced, mainly from documentary sources, that the more civilized people of Central America attained in Precolombian times the

All cosmogony begins with a created earth and that earth is mother of gods and men. From the under world, a cavern in the earth, men crawled to the surface through an opening called the sipapû. Races, like individuals, grew or were born; there is no hint as to how mother earth was created.

The highest supernatural beings were deified forces of nature endowed with human or animal forms. Among these were sky gods, earth gods, and their offspring in the early times when the race of man was young. The pueblos deified the sun and called him father of all, and so important is the place that he plays in their beliefs that they are ordinarily called sun worshipers. They endow him with human form, speaking of the disk as his mask. Each day he is thought to rise from his home in the under world and at night sinks into a western house. The pueblo Indians live in houses. Their chief supernatural has a house, as indicated by their use of this word for his place of rising and setting. The sun is a benificent being all powerful to bring the rains. In other parts of America among warriors he is appealed to to destroy enemies. Among those people whose environment necessitates rain he is regarded as all powerful for that purpose. Like ancient Aryans, the Tusayan Indians pray to the rising sun for blessings, but the meaning of the word "blessing" is always rain, that the farms may be watered and the crops grow to maturity. The worship of the sun, therefore, is of great importance; it pervades all the ritual, but it is always with one intent—the overpowering need of the agriculturist for rain in a desert environment.

As I have used the word "prayer," it may be well for me to point out the signification of this word among these people. We are dealing with a race in that stage of culture where the symbolism is all-important. Their word for prayer is, "scatter," that is, to scatter sacred meal. When a Tusayan priest addresses a supernatural being of his mythology he believes he must do so through the medium of some object as a prayer bearer; he breathes his wish on meal and throws this meal to the god. The prayer bearer is thought to have a spiritual double or breath body which carries his wishes. It is an old idea with him, reaching back to fetishism, for his breath with the talismanic words is the spell which brings the desired results. It must be mentioned, however, that oftentimes ethical ideas are associated with Tusayan prayers for rain, and I have frequently heard the priests at the close of their songs

monotheistic stage of supernatural concepts, and if that evidence is unimpeachable it would not be improbable that traces of the same should be found among pueblos. Unfortunately, however, the evidences on this point are none too strong, the probabilities that the writers and the documents did not eliminate their own interpretation too great. The pueblos at present have an idea of a supreme spirit, but there is every reason to believe it is of exotic derivation in the time since Coronado. However honest may be the modern priest who may say that he learned from his grandfather certain current beliefs, the crucial test of their prehistoric character must come from proof that the grandfather's testimony is correct. The sources of error in stories passed down by word of mouth through many generations are too many to permit us to pin much faith to traditions reputed to be of great age.

for rain exclaim, "Whose heart is bad, whose thoughts are leaving the straight path," and as they bewailed that the rains were delayed, sorrowfully resumed their songs and incantations.

An individual intrusts his prayer to sacred meal, but a society of priests has a more powerful charm. In the formal worship by a society of priests this prayer bearer becomes more complicated by appendages. It is furnished with accessories, all of which are symbolic. The meal is placed in a corn-husk packet surrounded with symbolic charms, feathers of birds which love water, herbs which grow in damp places. Such a prayer bearer with symbolic attachments is called a paho, and as if to betray its meaning in its name, the exact translation of this word is the water-wood, the wood which brings the water. These prayer sticks have many different forms, but are always called by the generic name, water-sticks. As their form becomes complicated by reason of symbolic accessories, their manufacture is an act which takes time, and as the prescribed symbols are known only to the initiated, their construction gives rise to a complex series of secret rites. The paho itself is a sacred object, consequently whittlings from it, fragments of string, corn husks, or feathers, used in its construction, are also sacred and must not be profaned. They are, therefore, carefully gathered up and deposited with a prayer in some sacred place.

The simple act of breathing a prayer on a pinch of meal is all sufficient in an individual's use of prayer meal, but in the complicated paho this simple act is insufficient in their belief. The prayer bearer intrusted with the prayers of a community of priests must be laid on an altar, smoked upon, prayed over, and consecrated by song before it is deemed efficacious. The production of this altar, the fetishes which stand upon it, the formal rites attending the ceremonial smoke, and the character of the songs thus develop each its own complex series of rites. Lastly, even the casting of the meal has led to complications. The paho must be offered to the god addressed in a dignified manner worthy of its object and the care used in its consecration. A special courier carries it to a special shrine. He is commissioned to his task with formal words, and he places his burden in the shrine with prescribed prayers. It has thus been brought about that the manufacture, consecration, and final deposition of the elaborate paho or stick to bring the rain occupies several hours, and when repeated, as it is in all great ceremonies for several consecutive days, makes a complicated series of rites.

The ritual of the Tusayan Indians is composite as their blood kinship. Peoples from other parts of the arid region have joined the original nucleus, each bringing its rites and its names of the sun god. Each of these components clung to their own ceremonials, and thus several series of rites developed side by side, adding new names to supernatural beings already worshiped. This state of things is not peculiar to Tusayan. Ra, the Egyptian sun god, has not more aliases than Tawa, the solar deity of the Mokis. So receptive is the Pueblo

A TUSAYAN PAHO.

system in point of fact that they are quite willing to ingraft the Christian ritual on their own, and in some of the modified pueblos of the Rio Grande we find the two coexisting. The sun especially has many names among these people, attributal or incorporated, derived from colonists among them. While it oftentimes puzzles the student to identifiy them, it causes no trouble to the primitive mind, who gladly accepts the medicine of all people, friends or enemies. Of synonyms of the sun, one of the most potent is called the Heart of the Sky.

In the mythology of the American Indians the worship of a mythic serpent is widely associated with that of the sun. Among the Pueblos this serpent appears as the Great Plumed Snake. This personage was a marked one in the Mexican and Central American mythologies. He is found carved in stone on the stately ruins of Chiapas and Yucatan, painted in fresco on the necropolis of Mitla, and represented in stucco on the façades of other high temples of Mexico. As the most powerful of all the divinities of the Nahuatl and Aztec peoples, he has crept into all the mythologies where traces of Nahuatl words can be detected. In Tusayan the Great Plumed Serpent is a powerful deity to bring the rain, and is associated with lightning, his symbol. By simple observation the untutored mind recognizes that rain follows lightning, and what more natural than that it should be looked upon as the effect. He therefore worships lightning because of this power. The course of the lightning in the sky is zigzag as that of the snake, both kill when they strike. The lightning comes from the sky, the abode of the sun and rain god, and the simple reasoning of the Tusayan Indian supposes some connection between the lightning, snake, and rain. The sustenance of the primitive agriculturist comes from the earth, and if the soil is nonproductive the sun and rain are of no avail. The Tusayan Indian thus recognizes the potency of the earth and symbolically deifies it as the mother. Consequently earth goddesses play important rôles in his mythology, and here likewise the composition of the tribe shows itself in the many names by which the earth mother is designated. We find her called "Mother of Germs," "Old Woman," "Spider Woman," "Corn Maid," "Growth Goddess." Strangely enough to us, but by no means strange to a primitive mind, this latter is associated with fire; for in the Indian conception fire itself is a living being, and what is more natural than association of fire and growth?

Before we pass to a consideration of the lesser gods of Tusayan there remains to be considered, among those of primary importance, a strange collection of concepts, the direct outgrowth of sun worship. I refer to what are known as the gods of the world quarters or cardinal directions.

The constant observation of the sun has led to an intimate study of the position of this luminary in different seasons, especially in his variation in places of rising and setting. As is well known, the sun, on account of the obliquity of the ecliptic, rises and sets at different points on the horizon at different dates, varying with latitude, between

certain distances north and south. The intervals on the horizon between extreme northern and southern azimuth is mapped out by a society of sun priests, who note the tree, hillock, or depression in the horizon from which the sun rises or into which he seems to sink at each interval, and thus determine the time for ceremonials with surprising accuracy year by year. The solstitial points of the sun on the horizon thus came to be cardinal points, two of which are called sun houses.[1]

As the four solstices are marked epochs in the sun worship of an agricultural people, the points of rising and setting at these times, or their cardinal points, are associated with minor deities, offspring of sun and earth. These are the positions of the sun houses. Naturally, his children live in these four world quarters, and from that primitive idea is evolved the worship of the so-called world-quarter deities which play such a prominent part in the Tusayan ritual.

Ancestor worship has developed into an elaborate system of minor supernaturals called Katcinas, most powerful, in their conception, to bring blessings, another name in their vocabulary for rain. It would be instructive to trace the origin and define the character of these beings if time permitted. Their name is legion, their ceremonials complicated.

In addition to the deification of the forces of nature, totems of animals, and ancestral personages, Tusayan supernal concepts are almost infinite in variety and number, many of which are simply modified fetishes, the heritage of archaic conditions. To define the character of a tithe of these concepts would be a task too technical for general discussion. Among a people where gods are so numerous, every hostile one must be appeased, no beneficent personage forgotten. From one end of the year to another there is almost a constant round of ceremonials, to describe which in detail would tax your patience.

Fortunately, however, these ceremonials admit of a classification. In one way we may say that the ritual of a people is the sum of all ceremonials which recur with precision in successive cycles. The time commonly adopted by primitive people is a natural epoch, the year determined by the course of the seasons.

Minor divisions of this year, or months, are characterized each by a special ceremonial, so that roughly speaking we may say that each ceremonial year at Tusayan is composed of thirteen great ceremonial events, one for each lunar revolution.

In the most elaborate of these monthly ceremonials occur rites lasting sixteen days, with four additional days for purifications. In the celebration of many the time is curtailed, but no moon shines over

[1]The horizontal positions of the sun at the solstices were probably recognized as cardinal by other peoples of agricultural life. The reader who is interested to follow this subject further is referred to various works on the orientation of Egyptian temples.

Tusayan without witnessing a religious festival of great complexity and prescribed precision, which is repeated every year at the same time.[1]

From this complicated series I will choose two great ceremonials to illustrate the two most important phases of the influence of aridity. These two occur in consecutive months, August and September, are both celebrated in extenso, and will for that reason give a fair idea of the nature of the elaborate components. Both are characteristic of Tusayan, although represented in a somewhat modified form in other pueblos.

The first is called the Snake Dance, the second the Lalakonti. The one is performed by male priests, the other by female; the former an elaborate prayer for rain, the latter for growth and an abundant harvest of maize. Both in their respective way illustrate the modifications developed by the climatic conditions. So complicated are they, however, that I must limit myself to the barest sketch of some of their more striking features.

No better ceremony could be chosen to illustrate the effect of the arid environment than the well-known Snake Dance, the most weird rite in the Tusayan calendar. This dance occurs every summer on alternate years in five of the Tusayan villages, and although a dramatization of an elaborate sun-serpent myth is so permeated by rain ceremonials that it has come to be an elaborate prayer for rain.

The worship of the serpent occupies a most prominent place in the ritual of all barbarous people where each environment has stamped it with special significance. Among the Tusayan Indians there are most complicated rites of ophiolatry, in March,[2] where six effigies of the Great Plumed-headed Snake are exhibited in the secret rooms in connection with symbols of the sun, in a strange dramatization. These ceremonials, however, have to do with the fertilization of maize and might well be chosen to illustrate rites which pertain to the necessities of agricultural people.

It is to that ceremony[3] where reptiles are carried fearlessly by the

[1] For analysis of the Tusayan calendar, see Provisional List of Annual Ceremonies at Walpi. Internationales Archiv für Ethnographie. Bd. VIII, Heft. V and VI. Leyden, Holland.

[2] The Palülükonti; A Tusayan ceremony. Journal of American Folk Lore, October–December, 1893.

[3] For an account of the Snake Dance at Walpi, see Journal of American Ethnology and Archæology, Vol. IV; Houghton, Mifflin & Co., Boston. I have elsewhere pointed out the small part which the Great Plumed Serpent plays in this ceremony, and the absence of fetishes or idols of this personage in the secret portions of the ceremony. The only symbol of the plumed snake which is found is on the kilts of the snake priest. As nearly as I can judge of its place in the components of primitive supernatural concepts, it seems to be an example of animal totemism and ancestor worship in which special powers to bring the rains are believed to belong to the reptiles, descendants, like the living participants, of a snake mother. The conditions are so often paralleled in the beliefs of other primitive people that there seems to be no exception among the Hopi. Cf. King, op. cit., Vol. I, pages 165–207.

snake priests, their younger brothers, as they believe, to which I especially refer, and to which I wish to call your attention. It is impossible for me in the limited time at my disposal to give even a sketch of this complicated rite, so weird and startling in its character as to rival the most heathen ceremony in the wilds of Africa. Yet this uncanny dance in all human probability will be performed in August of the present year in our own country in a Territory which justly aspires to be a State. The participants in it by treaty obligations are citizens of the United States and their children pupils of the public schools.

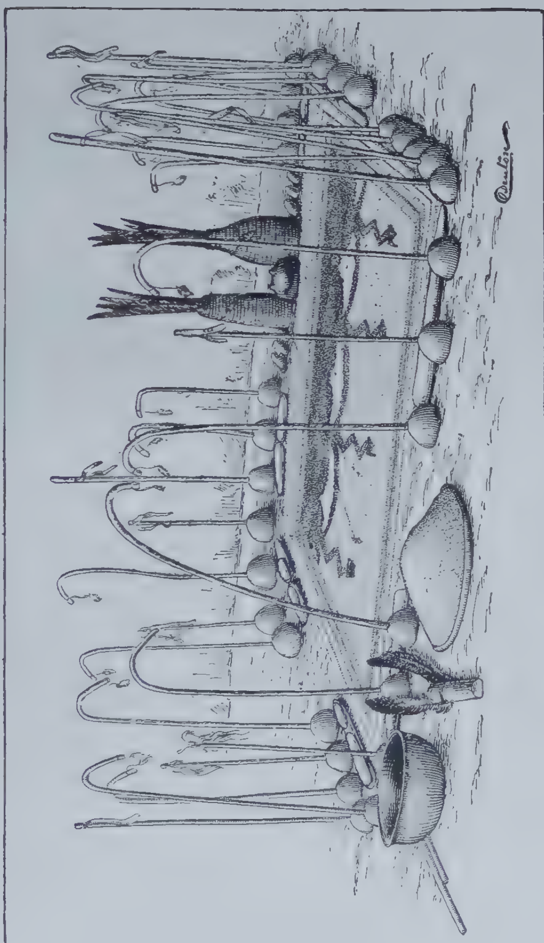
There is little doubt, however, that this survival of aboriginal ceremonials will soon become extinct, although up to the present time it has been but little modified by the new environment which the white men are bringing to the Tusayan Indians. The ceremony is not a haphazard or temporary invention of priests to entertain, but a part of a serious, precise ritual which has survived from prehistoric times to our day. Fifteen years ago the existence of this dance was practically unknown, and to-day, after searching study, comparatively little has been discovered. It may be wholly abandoned before the scientific man is able to collect material enough to make out what it all means.

In order to consider some of the elements of rain-making rites in the Snake Dance and accompanying secret ceremonials, let us first turn to the altars used in this dramatization. The celebration of this uncanny rite is performed by two religious societies or brotherhoods, which are known as the Antelope and Snake priests. The secret ceremonials of each of these priesthoods are very complicated and are performed in subterranean rooms called kivas into which uninitiated are debarred entrance. Each of these societies has in its own kiva an altar of complicated nature about which the ceremonials of a secret character are performed.

The altar of the Antelope priests is of especial interest to us in considering the rain-making motives of the ritual. It consists of an elaborate mosaic or picture made of six different colored sands spread on the floor and surrounded by a border of the same material.

The picture represents sixteen semicircular figures of four different colors, the symbols of rain clouds of the four cardinal directions. From one side of this composite picture are drawn parallel lines representing falling rain. This sand picture, with accompanying fetishes, is known as the rain-cloud altar, the home of the rain clouds.

Seated about this altar for seven consecutive days the Antelope priests daily sing sixteen songs to consecrate prayer sticks, which are later deposited in shrines to the rain gods. These prayer bearers consist of two sticks painted green and tied together midway in their length. At the point where they are bound is fastened a small packet of sacred meal, while to the same is also bound a feather of the wild turkey. This feather is aptly chosen, for the turkey is associated in



ALTAR OF THE ANTELOPE PRIESTS IN THE SNAKE DANCE.

their mythology with a time or place when the surface of the earth was muddy, and as they say the black tip of the feather was colored by the turkey dragging his tail in the black mud. To this prayer bearer is likewise attached two herbs—one male, the other female—plants which love the water. There are many other prescribed details in the manufacture of this prayer stick with which I will not weary you, but there is one point which may be of interest. The prayer bearers or prayer sticks of the first day are made as long as the longest finger of the left hand, and are carried to four shrines of the cardinal points, each of which is about 7 miles from the pueblo. The length of these prayer sticks diminish each day, and in the same ratio the distance of the shrines decreases. On the last of the seven days the prayer stick is the length of the ultimate joint of the middle finger, and the shrines in which they are placed are just outside the town. The intent of the prayers and songs intrusted to these prayer sticks is for rain. The courier who carries them each day is an important priest, and his explanation of why he proceeds in certain ways in his duty may interest you.

He runs swiftly through the whole circuit except when kneeling at the shrines, and is barefooted and naked, that the rain gods may notice him and respond with equal haste to the prayers which he bears. He loosens his hair and lets it hang down his back, symbolic of the way in which he believes the rain gods carry the falling rain which his hair symbolizes. He makes the far circuit on the first day because rain gods dwell far away beyond all cultivated fields. He runs in a circle that all the rain gods may see him. The priests hope the rain deities may notice their courier who bears their offerings to the shrines, and that each day they may come nearer. Hence, on each succeeding day the courier travels on a shorter circumference. It is thus they wish the rain clouds to approach nearer and nearer and pour down their contents on their houses and fields, that the dry river beds may be swollen with water and all farmers hear the pattering rain.

Consider one of the many episodes about the altar in the consecration of the prayer offering. Smoking, as is well known, was in Precolumbian times a ceremonial custom among the aborigines of the Southwest, and in the ritual of the present pueblos every great rite opens and closes with a formal smoke. The pipe lighter is an important functionary, next in rank to the chief, and in passing the pipe certain prescribed usages are always followed and terms of relationship exchanged. The sixteen songs of which I have spoken are divided into two groups of eight each by a unique observance—the smoking of the great cloud pipe. In this ceremony four different kinds of herbs are loaded into a conical pipe, and at a signal the pipe lighter passes a live coal to the chief, who places it in the larger end, kneels down behind the altar, places the larger end of the bowl in his mouth and blows four long whiffs through the pipe upon the sand picture of the altar. The smoke thus

formed is called the rain cloud, which it symbolizes, and the act a prayer to bring the rain.

Let us consider the final public event of the Snake Dance, that so often described, when the snake priests handle venomous reptiles, apparently without fear, in the presence of spectators. This uncanny proceeding has the same intent as the secret rites of which we have spoken—a ceremony for rain. The reptiles are believed to be elder brothers of the priests, and they are gathered from the fields on four successive days to participate in the ceremonies. It is believed that these reptiles have more power to influence supernatural beings than man, and as the acme of the whole series of nine days' observances they are thrown in a heap on the ground in a circle of sacred meals, and the chief of the antelopes says a prayer to the struggling mass, after which they are seized by the priests and carried to the fields commissioned to intercede with rain gods to send the desired rains. In fact, the whole series of rites which make up the snake celebration is one long prayer of nine days' duration, filled with startling components the details of which would weary rather than instruct you.

Let us, therefore, turn to another component of the Tusayan ritual which occurs each year in the month following that in which the Snake Dance occurs, the ceremony of the women priests for the maturation of the corn. I refer to the September rites called the Lalakonti, celebrated by a priesthood of the same name.

The ceremony for growth of the crops, which is practically for the harvest of maize, is directly the outgrowth of those climatic conditions which have made the Tusayan people agriculturists. A failure of this crop means starvation, and maize is far from a spontaneous growth in those desert sands. Hence the elaborate nature of the appeals to the supernatural beings which control this function. This great ceremony is naturally of special concern to women, the providers. The corn is the mother, the corn goddess the patron deity of women; the women are chiefs in this their special ceremonial. In turning over the mass of details which have been recorded concerning the festival of the Lalakonti it has seemed to me that I could not better illustrate the points which I especially desire to develop than to explain the altar used by these women priests in this ceremony.

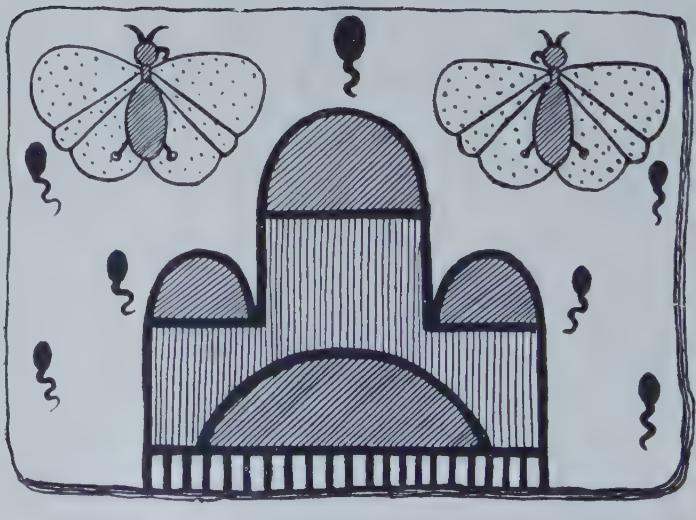
The altar[1] is erected in a subterranean secret chamber entered by a ladder through the middle of the roof; and around this altar are performed many rites the intent of which is an appeal to the gods of growth for abundant harvests.

There are two upright slats, painted with symbolic designs, among which the figures of the rain cloud and falling rain and the lightning which accompanies the rainstorm are most prominent. Back of the altar are sticks serving as symbols of the lightning, the zigzag ones

[1] For description of the Lalakonti altar, and ceremonials performed about it, see American Anthropologist, April, 1892. Washington, D. C.

THE LALAKONTI ALTAR.

FOUR EFFIGIES OF THE LALAKONTI ALTAR.



SYMBOLIC FIGURES OF RAIN CLOUDS ON TILE USED IN SNAKE DANCE.

representing the forked and the straight the sheet lightning. Two coronets, one on each side of the alter, are worn by two of the chiefs and they are made in the form of rain cloud symbols, semicircles from which parallel lines representing falling rain are drawn. Here, therefore, we see several rain symbols in prominent places. But the ceremony in which this altar is used is primarily one for the growth of corn; let us examine the objects in it with that thought in mind.

Four effigies or idols between the uprights of the reredos represent the following personages: The one to the right is the goddess of growth. She carries in her belt prayer offerings for abundant harvests. At her feet is an effigy of the corn mountain, colored with different colored corn, since all kinds of corn are under her control. In her left hand she has a small jar of holy water, since corn can not grow without moisture. The figure at her left is the patron goddess of the society who celebrate growth ceremonials, the ancestral deified totem of the fraternity. At her left is the corn goddess, since corn is the one cereal whose growth is desired. This figurine bears on her head the symbol of the ear of maize. No field of corn may be harvested without the protection of the warrior in a country harassed by enemies, and the fourth effigy represents the god of war, whose effigy naturally has a place on this altar. The white meal which is sprinkled on the heads of all the idols represents the prayers of the faithful, for as each priest approaches the altar she breathes her prayer on sacred meal and scatters it on the heads of the effigies. These prayers are for a good harvest, a successful crop and abundant rains.

There are three objects in front of the images which are the badges of the priests, called the "mothers." In advance of these, spread on the floor, is an elaborate picture, made of different colored sands, representing on one side the Earth Goddess, and on the other the Watcher, or little War God. Connected with the altar is a bowl with terraced rim, used as a medicine bowl, and a single upright ear of maize with a feather, a kind of standard, which is placed at the pathway of the kiva to warn uninitiated persons not to intrude on the mysteries which are performed about the altar.

The influence of arid climatic conditions is shown in the character and intent of symbols. The conventional figure of the rain clouds and falling rain is depicted more than any other on various paraphernalia of worship. It is painted on the altars, drawn in sacred meal on the floor of his sacred rooms, or kivas, embroidered on ceremonial kilts. The priest wears it on his marks and paints it on the body. It is an omnipresent symbol.

By a natural connection it is often replaced by figures of animals or plants associated with water. The frog and tadpole appear when the rain is abundant, and for that reason the priest paints the figures of these animals on his medicine bowl, or places effigies of it on the altar. In certain rites he makes clay balls, in which he inserts small twigs,

which he believes will change into tadpoles, and deposits them along dry water courses for the same reason, that rain may come. So shells from the great ocean are likewise esteemed as bringers of water, and fragments of water-worn wood are carefully cherished by him for a like purpose. The dragonfly which hovers over the springs, the cottonwood which grows near the springs, the flag which loves the moist places, becomes a symbol of water. Water itself from the ocean or from some distant spring, in his conception, are all powerful agents to bring moisture. There can be but one reason for this—the aridity of his surroundings. Not alone in pictoral symbols does he seek to bring the needed rains. The clouds from which rain falls are symbolized by the smoke from the pipe in his ceremony, and he so regards them. He pours water on the heads of participants in certain ceremonials, hoping that in the same way rain will fall on his parched fields. Even in his games he is influenced by the same thought, and in certain races the young men run along the arroyos, as they wish the water to go filled to their banks.

To our ways of thinking these are absurd ways in which to bring the rain, but to a primitive mind it is a method consecrated by tradition and venerated from its antiquity.

Symbolic figures of maize, the national food of the Hopi Indians, are no less common on ceremonial paraphernalia than those of rain. Maize is painted on the masks of sacred dancers and represented by effigies on altars. It gives names to several supernatural beings. Every babe, when 20 days old, is dedicated to the sun and receives an ear of corn as its symbolic mother. The badges or palladia of religious societies are ears of corn wrapped in buckskin—symbolic, no doubt, of the time when seed corn was the most precious heritage and preserved by the chiefs. The foremost supernatural being in the Tusayan Olympus is the Corn Maid, who is figured on food bowls, baskets, and elsewhere.

It can hardly be necessary for me to adduce more facts in support of the hypothesis that these two elements of the Tusayan ritual which reflect the climatic surroundings are ceremonials for rain and those for the germination, maturation, and abundance of agricultural products. The necessities of life have driven man into the agricultural condition, and the aridity of the climate has forced him to devise all possible means at his control to so influence his gods as to force them to send the rains to aid him. Wherever we turn in an intimate study of the ceremonials of the Tusayan Indians we see the imprint of the arid deserts by which they are surrounded, always the prayer for abundant crops, and rains for his parched fields.

When one makes the Tusayan ritual a special study he finds it wonderfully complicated in the development of details. No Hopi priest lives who understands the meaning of all these details, nor does he care for an explanation of them. There are two fundamental factors, however, which he can comprehend, and these are always on his lips when an explanation of the ritual is solicited. We cling to the rites of

our ancestors because they have been pronounced good by those who know. We erect our altars, sing our traditional songs, and celebrate our sacred dances for rain that our corn may germinate and yield abundant harvest.

The town crier calls at dawn from the house top the following announcement, which is the key to the whole explanation of the Tusayan ritual:

> "All people awake, open your eyes, arise,
> Become Talahoya (child of light), vigorous, active, sprightly.
> Hasten clouds from the four world quarters;
> Come snow in plenty, that water may be abundant when summer comes.
> Come ice and cover the fields, that after planting they may yield abundantly;
> Let all hearts be glad;
> The knowing ones will assemble in four days;
> They will encircle the village dancing and singing their lays * * *
> That moisture may come in abundance."

I have limited myself to showing that the arid climatic conditions are reflected from the rites of one tribe of Indians, and it would be instructive to see whether these facts are of importance from the comparative side. There are other equally arid regions of the globe where we might justly look for the same results if this climatic condition is as powerful in the modification of cults as implied. There are marked similarities in the climate of Arabia, of Peru, and of Assyria, and as a consequence startling resemblances in their rituals. But there are many differences; and we thus detect that our analyses of causes has not been complete or ultimate, for we have limited it to but one powerful element in the modifications of ceremonials.

Environment is a complicated nexus of influences, organic and inorganic, threads of which we can successfully trace a certain distance, but which eludes as we go further. There are many effects where causes remain to be discovered, and many climatic influences on cults have yet to be clearly discerned.

A few words more and I have done. Theories among civilized men, like things among savages, may become fetishes. It would be lamentable if environment should become a word to conjure with, or if we should use it to cover ignorance of that which we can not explain. I have tried to show that one highly complicated ritual is so plastic that it responds to climatic conditions, but there are elements in it due to some other unknown cause. Because climatic conditions explain certain modifications in human culture the tendency would be to strive to make it do duty in explaining all. Such a generalization is premature and unscientific. The theory that differences of species of animals and plants were due to climatic influences may have satisfied the early students of evolution before Charles Darwin pointed out the law of natural selection. Environment is a factor which profoundly affects animals, but a struggle for existence in which the fittest survive is a law of evolution.

So environment is a potent influence on the culture of man, but there are laws, as yet not clearly made out, back of it which control the evolution of man.

When in the struggle for existence the fittest came to be measured by degrees of intelligence, and no longer by superiority of bodily structure, climatic conditions were still powerful to modify and stimulate thought. The increase in intelligence due to these agents did not develop a new species, for, to whatever heights he rises, man still remains *Homo sapiens.* If, then, the specific identity of all individual men on the globe to-day is true, the superstitions which we have studied are errors of minds like our own, but imperfectly developed and modified by environment. In her mistakes, said the great naturalist Geoffroy St. Hilaire, nature betrays her secrets. By a study of erroneous working of the mind and their probable causes we can discover the nature of mind. Below all ceremonials among all men, savage or barbarous, may be traced aspirations akin to our own since they spring from our common nature. Until some philosopher shall arise who can so analyze environment as to demonstrate that the great religious teachers of man, who, suddenly appearing, have stimulated the race to great bounds in progress, were solely the products of surroundings, we may believe that there is another most potent influence behind environment controlling the development of culture. Throughout all history man, from his own consciousness, has recognized that controlling influence to be higher than environment, and no science nor philosophy has yet succeeded in banishing the thought from his mind.

THE RELATION OF INSTITUTIONS TO ENVIRONMENT.

By W J McGee.[1]

THE RELATIONS OF ORGANISMS.[2]

The career of the organism, as individual species or larger group, may be considered as the resultant of two forces, viz, (1) the initial or directing force operating through heredity, and (2) the secondary or modifying force operating through interaction with environment.

The potency of environment in shaping the career of the organism is illustrated by the forest. Primarily the plant depends for existence on soil and climate, and vitality fails if these conditions are adverse; when soil and climate are measurably favorable the fitter plants strive for supremacy and some tower above their competitors. Commonly the trees bear multitudes of seeds, that the species may survive even though many seeds fall on stony ground and many young shoots may choke among brambles; the cypress, pine, and other trees combine to form dense and lofty mantles of foliage beneath which alien plants are smothered; and through these and other means forests are produced. Initially the tree strives against alien species, but when its kind comes to prevail the trees strive against one another and the strongest, loftiest, and hardiest survive; and thus internecine strife as well as strife against the alien makes for excellence among trees. So the forest is shaped by environment, beginning with external conditions and ending with the mutual relation between individuals; and the career of the forest tree is one of ceaseless struggle, chiefly against other plants, both akin and alien, through which all its features are molded.

The potency of environment in shaping organisms is still more clearly shown in desert lands. Here the strife for existence is chiefly between the organism on the one hand and the physical conditions of climate and soil on the other; here the plants strive to perpetuate their kind by individual longevity rather than by multiplication of offspring, so that with most species seeds are are reduced in number, while with some species fruiting becomes a disease, perhaps fatal; here

[1] Saturday lecture in Assembly Hall of the United States National Museum, May 23, 1896. Delivered in the absence of the author by Mr. Frank Hamilton Cushing.

[2] The first division of the address is a résumé of the earlier lectures of the series, especially of the five biologic addresses constituting the first course.

adaptive devices for checking evaporation and storing water, for protecting the plants from heat and cold, and for arming them against animal enemies, as well as for utilizing the energy of light, are developed; here all plants interact with the inorganic external in such manner that even unrelated species assume likeness in form and feature. In desert lands the strife for existence is not between plant and plant, whether akin or alien, so much as against sun and sand; and most of the organisms engaged in this common strife are forced thereby into a cooperation in which each benefits the other and in which finally all are united in a great solidarity of singular perfection. So the organisms of desert lands, especially the plants, are modified by environment in the direction of likeness in external characters, and in other ways, and are forced into a cooperative union transcending specific and even generic kinship; and thereby the flora is in large measure transformed, and the potency of heredity is masked through the adjustment of the organisms to environment, while vegetal clanship is exalted into plant sociology.

In humid and in arid lands alike heredity and environmental interaction are commonly antagonistic, and in this antagonism the strife for existence arises; but now and then, in the course of the development of organic forms, it chances that an organism enters an environment to which it is so peculiarly adapted that the struggle for existence is made easy through the conjunction of heredity with external relation, and in such instances the potency of vitality is strikingly shown. Such a case was that of the American buffalo which, about the time of transition of geologic modernity into historic antiquity, began to spread over the grass-covered plains of the mid-continent; so well adapted was his environment to his needs that his kind increased and multiplied a hundred fold; his rise was so rapid that he far outstripped enemies and expended his redundant energy in covering the hills and valleys with thousand-weights of moving flesh; but through generations of peace and sloth his vigor waned, his constitution weakened, and he fell an easy prey to the red man, and when the white man came he melted away helplessly. Commonly such spurts of vitality as that exemplified in the history of the buffalo result from human interference with the natural interaction of organisms. The European rabbit, when introduced in Australia, escaped the enemies and inimical factors of environment which had grown up with the species in the original habitat, and soon increased beyond anticipation, almost beyond belief; the western American rabbit found his environment changed by the introduction of fields and stock, and increased enormously; the English sparrow, the common daisy of Britain, a roadside plant of Mexico, and many other organisms introduced in the United States artificially have profited by freedom from natural enemies and have multiplied into pests. So, in many parts of the world, and at various times in the history of the development of organisms, the redundance of vitality, when relieved from the pressure of adverse conditions, has been exemplified; and it

is under these favorable conditions that the potency of heredity is most conspicuous, since the organisms are not fain, as elsewhere and other-time, to expend energy in shaping themselves to their surroundings.

The fertility of organisms in adaptive devices whereby they are fitted to adverse conditions of environment, shown clearly in the desert flora, is illustrated still more strikingly by certain insects. The walking sticks, the flying leaves, and a variety of creeping and leaping and winging insects adjust form and color to the vegetation on which they habitually rest so closely as to deceive enemies; stingless flies mimic the appearance and habits of stinging wasps and odorless insects counterfeit odoriferous bugs that they may escape molestation; and in many other ways insect species modify themselves for their own benefit under adverse conditions. The unrelated desert plants grow alike toward thorniness, waxiness, leaflessness, etc., to meet common needs, and thereby hereditary features are masked; but in insect mimicry the impress of heredity is lost and characters produced through direct interaction with environment replace legitimate features expressing biotic relation. Thereby the exceeding plasticity of the organism is displayed—a plasticity so perfect as almost to suggest that the initial force operating through heredity is as nothing, and that environmental interaction is as everything, in shaping the course of the vital stream.

The forest, the scant flora of the desert, the redundant vitality of species chancing to outstrip competitors, insect mimicry, all illustrate the potency of environment in determining the career of organisms considered as units, and indicate that primary characters are largely or perhaps wholly subordinate to derived organic characters produced by interaction with the external; and even when the organism is viewed as an aggregation of organs the same lesson may be read. The functionless splint bones of the horse are vestiges of digits which were useful organs in equine ancestors, as shown by the joint evidence of paleontology, embryology, and reversion; the functionless and troublesome vermiform appendix is shown by Lucas to be a vestige of a supplemental stomach useful to an herbivorous progenitor, but useless through several later stages of development; the feeble vestigial muscle by which one man in a thousand, and one infant in a hundred, is able to move his ear is an all but functionless organ, weakened and nearly lost through disuse: and the dozen or more vestigial structures known in man and the scores known in other organisms are but moribund warriors in the strife for existence, thrown out of rank and trampled over because of unfitness for battle against the great external—they may boast long lineage and noble station in the earlier stages of organic development, yet their past counts for nought in that ceaseless struggle in which activity is life and inactivity is death. So among organs as among organisms, many fall behind and are lost in the race for continued existence, and it is environmental relation rather than original character that makes for perpetuity.

The forest of humid lands, the flora of the desert, the foeless buffalo and rabbit and sparrow, and the mimetic insect illustrate the potency and persistence and indeed the predominance of characters acquired through interaction with environment, and the testimony of vestigial organs accords with the testimony of the organisms; and thereby the law of organic development is indicated. In general terms, this law is that *the characters of organisms are determined through interaction with environment.* It is to be observed that the law is general and that exceptional instances are to be looked for; yet it is to be remembered also that no indubitably exceptional instances are known. It is indeed a legitimate and desirable postulate that there is an inherent and persistent force in vitality, a force expressed in heredity and transcending environmental interaction; the postulate is legitimate since this component of vitality is represented in the life of each individual organism and in many of the characters of species, genera, and other groups of organisms; the postulate is desirable since it yields a sort of datum-plane from which the amount and kind of adaptive modification may be measured; yet it must not be forgotten that, as applied to the great aggregate of living things on the earth, the postulate is a postulate merely; and the law of organic development, individual, specific, and general, is that the characters of organisms are ultimately shaped by interaction with environment.

When the law of biotic development is extended to mankind, it appears to fail; for the men of desert and shoreland, mountain and plain, arctic and tropic, are ceaselessly occupied in strife against environmental conditions which transform their subhuman associates, and yet men remain essentially unchanged—some taller, some stouter, some swifter of foot, some longer of life than others, yet all essentially *Homo sapiens* in every characteristic. More careful examination indicates that the failure of the law, when extended to mankind, is apparent only. The desert nomads retain common physical characteristics, but develop arts of obtaining water and food, and these arts are adjusted to the local environment; dwellers alongshore do not suffer modification in bodily form, but their arts are modified and they become fishermen and sailors; the mountaineers do not acquire the physical characters of the subhuman animals of the mountains, but learn to use weapons and to protect themselves from bodily injury by artificial devices; the plainsmen remain human in body and limb, but learn to hunt and, borrowing knowledge from the desert, to herd lower animals; the men of the arctic do not emulate their fur-bearing and blubber-making associates, but adjust themselves to environment and begin the conquest of the earth through the making of clothes and the building of houses; and the dwellers beneath the equatorial sun hold to the human form, yet invent multifarious devices for overcoming hard environment through the aid of mind. Thus development, differentiation, transformation, are no less characteristic of the human genus than of lower organisms—

indeed, it is in this noblest of organisms that plasticity or adjustability to diverse conditions culminates—but the differentiation is intellectual rather than physical, cerebral rather than corporeal. Men were differentiated initially through arts of welfare by which they began transforming environment to their needs; later, arts of pleasure were developed out of the richness of a higher life, and for the first time in the history of living things smiles and laughter came to be on the earth: and as mind grew through exercise, arts increased and multiplied.

So human development differs in divers ways from the development of lower organisms. In the first place, it is fundamentally intellectual; in the second place, it is collective rather than individual; and in the third place, it tends directly, at first through convenience and later through design, toward the modification of environment and the conquest of the earth for human weal. Yet the law of modification remains essentially unchanged, for mental characters, like physical, are shaped by interaction with environment.

Since human development arises in arts, which are essentially collective, the career of the individual is in large measure subordinate to the career of the group; and since the parts of the group are interrelated, while groups are related among each other, the essential unit is the organization rather than the organism. The primitive organization is feeble and indefinite, perhaps to such an extent as hardly to distinguish man from lower animals; but as arts increase, and as internal and external relations multiply, the organizations grow definite and laws are gradually developed, and institutions, the last and best fruit of intellectual development, are born. So the institution springs from organization as organization is produced by arts, themselves the offspring of intellectual activity. These are the salient features of human development through interaction with the external. While the fundamental features of human development are thus essentially distinct, it is to be remembered that their germs are found in lower life. Many insects, birds, and other subhuman things possess simple arts, many gregarious and other animals are loosely organized, and among some articulates and vertebrates the organization is so definite as to imply law, none the less efficient because instinctive—indeed, just as the ascent of the human organism may be traced through structural homologies with the lower animals, so the ascent of organizations may be followed from a lowly beginning far down in the scale of biotic development up to a splendid culmination in humanity and human institutions.

THE RELATIONS OF ORGANIZATIONS.

On humid and temperate lands and in shoal waters life teems, and the bitterest strife is between organism and organism. In the sun-parched and snow-mantled deserts of the land surface and in the chill deserts of the abysmal waters life scrimps, and the strife is between organism and inorganic environment. Thus there is a law of strife for the fecund district and another law for the desert.

Manifold results flow from the strife of the desert. Since only a few organisms can be maintained, each strives to perpetuate its kind, not by multiplying progeny as amid softer surroundings, but by prolonging the life of the individual and economizing in reproductive energy. Thus plants and animals live long and leave scant offspring. Since the organisms are few, species can be perpetuated only through individual vigor, and each strives for this and other qualities of individuality, so that the plants and animals are strong and hardy. Since the organisms are molded by interaction with the same physical agencies, they grow toward likeness in form and function to the extent that unrelated organisms assume similar characters. Finally, since the organisms are engaged in common strife, they spontaneously fall into a cooperation through which each assists alien neighbors in such manner that all are united against the common enemies of sun and sand.

There are many grades of cooperation depending on the number of species engaged therein. The shrub shelters the field mouse from the sun and the hawk, and the field mouse loosens and fertilizes the soil about the roots of the shrub, and the two dwell together in mutual tolerance, without enmity or intimate union. The insect comes to feast on the flowers and fruit of the shrub, and incidentally to spread pollen and to be devoured by the mouse, and thus plant and animal are linked in more intimate union by the mediate insect, the despoiler of one and the prey of the other, yet the benefactor of both. Then the grass springs about the burrows in the shelter of the shrub, and incidentally retains the scant moisture; the herbivore arises to consume the grass, but incidentally to spread the seeds of the shrub; birds gather to devour insects and fruits, and incidentally fertilize the soil and distribute seeds; and the carnivore comes to feast on flesh, yet incidentally to protect the shrub and grass by decimating the herbivores; and in this way the shrub and the mouse and all the other organisms are brought into an intimate union in which every habit, even individual enmity, makes for the common good. Thus the cooperation among the living things of the desert begins in tolerance and ends in solidarity—a solidarity so perfect and far-reaching that no organism exists beyond it, that every organism within its bounds is directly or indirectly dependent on its advantages, and that the sum of life is multiplied through its beneficence.

There are also several kinds of cooperation depending on intimacy of union. The shrub and the mouse and the insect are loosely linked, and each is free to come and go and reproduce after its kind, yet they spontaneously gather into colonies or communities to the extent that the prevailing life of the desert is communal. The farmer ant fertilizes the silver grass in an unknown way, and the grass flourishes and the ant subsists on its seeds, so that each furnishes food for the other and both increase and multiply apace; thus, although free to come and go and to reproduce each after its kind, the ant and grass are commensal,

and are benefited by the commensality to the extent that they spontaneously strive for this form of union. The yucca is fertilized by the yucca moth so regularly and persistently that it has grown impotent, while the moth nests in the plant for which it lives and would hardly survive divorce therefrom beyond a single generation; this is the cooperation of miscigenesis,[1] toward which many desert organisms have been driven in the strife for existence.[2] Thus the cooperation beginning in simple tolerance sometimes ends in bodily union—a union so complete that the component organisms are transformed unto each other and transfigured into an exalted unity far transcending individual or specific quality.

There are certain stages in cooperation defined by the organic (especially neural) rank of the cooperating organisms. When the shrub and mouse and insect unite in a community, the most highly organized member is the most independent and measurably dominates its associates; yet the unconscious domination is feeble and the communality is not greatly affected thereby—this may be called the stage of protoculture. When the farmer ant affiliates with the silver grass, or the honey wasp of Sonora with its nectar-bearing bush, the articulate dominates and molds to its unconscious will the nerveless and moveless plant; and though both organisms are benefited the higher profits the more, and is ennobled by conquest along the line leading to intellectual dominion—this may be called the stage of eoculture. When the nomadic ancestor of the Papago Indian long ago entered the solidarity of the desert, he dominated the herbivore and carnivore by craft as well as strength, and learned to scatter seed and fertilize soil by design rather than chance and to protect fruit-bearing plants, howsoever sown, unto the harvest; and since he strove against sun and sand with the plant and the lower animal, he was forced into the solidarity which he only dignified but dared not destroy, and entered, albeit feebly and haltingly, into conscious control of vitality—this is the stage of simple agriculture. As the prehistoric Papago became sedentary and began to divert and store water, small birds sought his domicile for protection, fowls gathered to glean his fields, and coyotes and vultures collected to scavenger his homestead; then, since the dove and turkey furnished eggs and flesh and the coyote sounded a larum at the approach of enemies, tolerance warmed to interdependence and the lower organisms passed collectively (for such is the way of natural taming) into domestication and later into artificialization for the behoof of mankind, yet to their own benefit—this is the stage of zooculture, or the higher agriculture. Thus the growth of cooperation begins with independent association

[1] Miscigenesis (see Winchell, "Preadamites," 1880, p. 80) was combined with commensality in an earlier discussion of the life of the desert ("The Beginning of Agriculture," American Anthropologist, Vol. VIII, 1895, p. 366), but discrimination is desirable.

[2] Loc. cit., also "Expedition to Seriland," Science, New Series, Vol. III, 1896, page 493.

and ends with interdependent association or organization—a hierarchic association of organisms in which each has special function and all have individual and collective profit, while all are dominated by the big-brained organism for the good of his world, be it small or large.

As time passes, local association grows into general organization. Each valley and hillside has a peculiar soil and water supply and tends to bring forth peculiar plants, so that such shrubs as scorn the charity of cooperation remain provincial.[1] When the plant offers sweet perfume, or sapid fruit, or nutritious nuts to the flying insect or wandering herbivore or migrating bird, its pollen and seed are carried into other provinces and its posterity enjoy an ever-increasing range of association; and thereby the force of life begins to overcome local hardness and the unselfish plant becomes a prophet of good, albeit of little honor in its own country. When a herbivore or fowl sacrifices tithes of toothsome flesh, it tempts carnivorous enemies, yet is thereby led from province to province and made to develop the individuality requisite for ultimate success in the strife for existence; and when beast or fowl communes with man, as did fleshly turkey with flesh-eating Indian, it enters on a nobler career which may carry it to the ends of the earth, so that its original home is lost in its general diffusion. While the human horde hugs the native heath, it wars with all other tribes; but as the huntsmen follow quarry into neighboring ranges they meet enemies, when the more savage are slain and the more peaceful survive and sometimes find favor among alien daughters, so that the tribes are united; and in this way clans are blent and provinces joined to the extent that peaceful arts arise and bind men, animals, and plants in far-reaching union. So it is that organization begins with escape from provincial barriers, and extends unto cosmopolite association—an association in which the selfish and scrimping are subordinate and the generous superordinate, while the humane in mind and heart dominate over all.

As time passes or as progress rises, organization grows into institutions. The migrant bird returns to its nest and the feral beast holds to its range and watering place, and thus property right arises, albeit vaguely; the colony of farmer ants clears a threshing floor a thousand ant-lengths across and cultivates a grass field thrice as great and lays highways to neighboring farms, and thereby individual and common property right are adjusted; the modern Papago inherits title to a spot of ground in the permanent village and to another spot in the temporale where crops are made, as well as to a share in the spring or storm freshet, while his water-storing ancestor must have acquired interest in irrigation works; so that property right springs among lower organisms and matures among men, growing definite through custom, the parent of common law. Among beasts, the family is the social unit

[1] The provincial character of the desert flora has been recognized by Toumey, Coville, and others.

and the sire or dam is the ruler thereof, and the young are led toward right and held from wrong according to the lights of the ruler, and thus social organization and ethical control arise together; in the human genus, sapient species, and Seri family the parental group appears to have grown into the clan in which the mother is householder, though the doughtiest warrior or shrewdest juggler is leader and lawgiver and controls his kin by fear, largely for selfish ends, while the body of common law changes materially with each succession in chiefship; in the Piman family and Papago tribe, the closer blood ties are strong, though the clan system is feeble, and the ruler is chosen for wisdom as well as courage, and is advised by a council of wise men and aided by subchiefs, each similarly guided by the old men of his village, and thus the government is beneficent according to the lights of the sages, and the body of law, albeit unwritten, is handed down from generation to generation with little change. So property right and jurisdiction arise among the more intelligent lower animals and spread widely among the peaceful Papago, whose unwritten laws are like unto the written laws of enlightened nations in beneficence of aim; and as justice blossoms and bears fruit in beneficent custom, provinces and clans and gentes wane and confederation waxes, and the governmental institution grows large and clear. Thus it is that the higher stages of organization begin with family rule and pass into civics—a series of institutions embodying the justice of wisdom, the mercy of humanity, and the strength of a union which transcends the harsh enmity of sun and sand and makes the wilderness to blossom—institutions only a little less firmly fixed because limned on the tablets of memory and linked through song and story, rather than graved on brass or printed in books.

Of such are the results flowing from the strife of the desert. The plants, animals, and men are forced into cooperation so intimate that few live unto themselves alone, most live for the general good; then, stimulated by the severity of the strife, cooperation begets intelligence which dominates the desert for the common good; thenceforth intelligence guides the communality, commensality, and miscigenesis from which it springs, and produces definite organizations of the organisms which are best for the most intelligent but good for all; and in time the organization matures in institutions binding the humans directly but at the same time binding the subhumans indirectly and uniting human and subhuman in a grander unity—the unity of intelligent life in a single nature-shaping power. The course of development is unbroken from lowly shrub to ruler of a principality, and from simple tolerance between shrub and mouse to beneficent law; and throughout the course from lowly beginning to noble ending, a single mode prevails—it is not so much the elimination of the unfit (for this is the cruel work of ruthless nature) as the combination of the fit into superorganic groups of ever-rising grade. So the bitter strife of the desert makes strongly for individual strength, but still more strongly for altruism with its attendant

organizations and institutions; and while it may not be denied that organizations arise under softer skies where organism strives against organism, it may be affirmed that the hard environment quickens the germ of combination whose blossom is law and whose fruit is enlightenment.

As institutions grow and spread they are fertilized and ennobled by contact with one another, much as languages and arts are enriched by blending. Along storm-swept shorelands abounding in sea-food, as about the Gulf of Mexico in olden times, primitive men gather to feast on the fishes and mollusks. Since individuals are unable to stem the tide and ride the storm waves without occasional or habitual aid from their fellows, industrial and social organizations arise, and in time the organizations mature in fixed institutions adapted first to the advantage of the family group or clan and later to tribal welfare. So prolific shorelands tend to produce populous tribes. Under the beneficent tribal institution the group expands and displaces ill-organized tribes, and eventually overflows into the interior; if the interior is adapted to the chase and petty fishing, the overflow retrogrades, but if it is so conditioned as to enforce industrial and social cooperation (as are all desert regions), the overflow improves through new organizations blending with the old, and the institutions become more general and still more beneficent. So shore lands abounding in aquatic life with adjacent desert regions seem to afford the conditions requisite for the development of civilized institutions, and it is the testimony of history that civilization sprung in regions so conditioned in the four great continents of the globe—Eurasia, Africa, South America, and North America.

As time passes and as institutions blend, beneficent law (which is the framework of the institution) re-creates the altruistic motive whence it sprang. Among hunters and petty fishermen disputes arise concerning the ownership of quarry, and these are settled by the leaders in the interest of peace and clan welfare, and thus laws are established and motives fixed which are collective rather than individual; yet, through habit, the motive is gradually impressed on the mind of each individual subject to the law. Thus justice is engendered. Among shoreland tribes disputes arise concerning labor, which is an impost on the strong for the benefit of weak and strong alike; much of the labor is performed beyond the reach of the leader who adjudicates disputes, so that testimony must be taken in order that justice may be done, and in time mendacity is condemned and veracity applauded; at first the blame and praise are collective and expressed by the wise men on the tribal behalf, yet in time individual interest leads to individual effort to secure praise and avoid blame, and law comes to be reflected in motive. Thus truth is engendered and justice strengthened. In the desert the young and thoughtless occasionally famish unless the more provident share their precious store of water, and to prevent weakening the group the leaders prescribe hospitality and derogate meanness; at first

the rule is fixed by the judges in the collective interest, but in time the custom comes to be followed as a motive by each normal individual of the group. Thus mercy is engendered. In boreal lands it is needful to lay up store against the long winter, and thereby thrift is developed and property right is strengthened, in connection with hospitality such as arises in the desert. At the same time life is endangered and the group weakened through predation, and thus, in the eyes of the sages, theft is the gravest of crimes and is severely punished. At first the regulation is collective in the general interest, but in time the fear of punishment and the hope of commendation become habitual, and the habit of uprightness grows into upright motive. Thus probity is engendered. Other environments tend toward the development of special provisions designed to promote welfare under the special conditions. Always these laws bud as collective regulations, burgeon as individual habits, and blossom as altruistic motives, which duly fruit in improved laws; and thus justice, truth, mercy, and probity come up to glorify mankind.

So organizations which find their germ among the lower organisms attain full development only among enlightened men. At first the organizations are local and reflect the local environment; they grow into institutions, which in like manner reflect the surroundings of the people by whom they are framed; through contact and commingling of peoples the organizations are enlarged and the institutions enriched and made more beneficent; and the institutional laws pass into motives and become the noblest of human characters. In the beginning the organizations, institutions, motives even, are of the earth earthy, and, like the provincial flora or fauna, pertain to the tract in which they were developed; but through combination of the good and condemnation of the bad as the organizations spread, they are exalted ever higher and higher in the perfection of humanity. Such is the history of the past, and such the promise for the future.

THE CENTENNIAL OF THE INSTITUTE OF FRANCE.[1]

By Jules Simon.

Gentlemen: When General Bonaparte took command of the Army of Egypt, he immediately signed his proclamations and orders: "Bonaparte, General in Chief, Member of the Institute of Frence," "which would be sure," said he, "to be understood by the lowest drummer."

The institute was then not three years old. It has since that time made some noise in the world. I may not flatter myself, therefore, that I can teach anyone its short and glorious history for the first time. I shall sum it up in a few words, in order that we may rejoice together over its achievements, but by no means that we may learn to know them.

The great assemblies which at the end of the eighteenth century took the fate of France into their hands had from the beginning revolutionary instincts. The end they had in view was not to preserve existing institutions by improving them and by purging them of their abuses. They simply swept away all they found to exist, and, when they had overthrown everything, they felt at liberty to go to work and reconstruct it all.

The academies had aided largely in bringing on the revolution. Hardly had they passed from theory to action when they perceived that they were going too fast. They had wished to reform, but all around them people thought only of destroying. The revolution, on its side, as is the way with all revolutions, forgot what had been given to it, and became exasperated over what was refused.

It confined itself at first to unfriendly measures. The Constituent Assembly voted with hesitation and only provisionally, for one year, the appropriations which the finance committee demanded for the literary associations,[2] accompanying, moreover, the vote with sharp reproaches. The convention struck some heavy blows. In the first

[1] Discourse by M. Jules Simon, president of the Institut de France, at the centennial anniversary, at the Sorbonne, Paris. Translated from Nature, vol. 52, No. 1357, October 31, 1895.

[2] For the French Academy 25,217 livres, besides 1,200 livres for a prize to be offered; for the Academy of Belles-Lettres, 43,906 livres; for the Academy of Sciences, 93,458 livres; these two academies were also to offer a prize of 1,200 livres each.

place, it forbade the vacant places to be filled again, and, finally, in August, 1793, it suppressed all the academies and literary associations established by the nation.

It has often been remarked that this very revolution which had suppressed all academies, created the institute, which is an academy. This was not inconsistent on the part of the assemblies. The idea of creating an entirely new and complete academy was contemporary with the resolution to make an end of the old academies. The Constituent Assembly had directed Mirabeau to submit to them a plan for a national academy. Mirabeau called in Chamfort, who was just then engaged in a quarrel with the French Academy; hence he wrote a violent diatribe and prepared a plan which Mirabeau never found time to read from the tribune.

Plans for a national academy were numerous under the convention. Condorcet, d'Alembert, Daunou, Talleyrand, all who had high aims, presented their contributions. It is said that Talleyrand accepted the paternity of a scheme, which was entirely the work of the Abbé Desrenandes, who had been his vicar-general at Autun, and who was known to have been a member of the council of public instruction.

Talleyrand was one of those who could have dispensed with the aid of a secretary, but the tradition is both old and persistent. All who had formed plans for a national academy jealously laid claims to the glorious title of founder of the institute. But historic truth compels us to inscribe another name at the head of this list of honor, and that is the name of Richelieu, the founder of the French Academy.

We, of our day, are more just than our fathers were. Our admiration for the great achievements of the revolution does not blind us to the glories of the monarchy, which are the glories of France. We celebrate the centennial of the Institute of France, but we are perfectly ready to associate with the glory of this day the founder, or rather the founders of the academies, from whom the institute has inherited its glory: Louis XIII, and Louis XIV, Richelieu, Séguier, and Colbert. The institute has been in existence since October 25, 1795, but the academies of which it is composed go back to 1635. Most assuredly the Institute of France counts, from its foundation, among its members a number of illustrious men. I shall quote some of the names, regretting only that I can not mention them all: Chateaubriand, Victor Hugo, Lamartine, Alfred de Musset, Alfred de Vigny, Guizot, Thiers, Cousin, in the French Academy; Monge, Berthollet, Lagrange, Laplace, Lavoisier, Fresnel, Ampère, Arago, Cuvier, Geoffroy Saint Hilaire, Cauchy, Chasles, Claude Bernard in the Academy of Sciences; Daunou, Victor Le Clerc, Littré, Boissonade, Hase, Naudet, Burnouf, in the Academy of Inscriptions; Louis David, Ingres, Delacroix, Meissonier, David (d'Angers), in the Academy of Fine Arts. I had ended here the list of our glorious contemporaries in obedience to the law which does not permit me to mention the name of anyone living at the

present time—must I add to-day the name of a man whom I knew more than fifty years ago at the normal school, where he was a pupil and I a professor, who was a friend to every one of us, since no one could know him and not love him, and who was, above all, the friend and benefactor of mankind, the immortal name of Louis Pasteur? The roof of this hall still resounds with the echo of the acclamations that welcomed him when he came to this very place to receive the homage of the whole scientific world. Mankind, on that day at least, was grateful and just.

Thus the Institute of France has had, since the beginning, a magnificent membership of great men. We are proud of our new glories, but we preserve a grateful and filial worship for the heroes of olden days. We do not renounce Corneille, Racine, nor Boileau, nor La Fontaine, nor Bossuet, nor Voltaire, nor Montesquieu, nor Buffon, nor Clairant, nor d'Alembert, nor Huyghens, nor Mariotte, nor Mabillon, nor Rollin, nor Turgot, nor Lebrun, nor Mignard, nor Lesueur, nor Philippe de Champagne, nor Mansart, nor Soufflot.

Gentlemen, the tricolored flag is still for us "the beloved flag;" it is the star of liberty and of civilization, but we follow with love and pride in our hearts the white flag with the lilies of France as we go back from age to age to the century which was the great century, and which remains, emphatically, the "French century."

It was on the 29th of January, 1635, that the French Academy received its official consecration. The Academy of Fine Arts enjoyed the same honor in 1648, the Academy of Inscriptions in 1663, and the Academy of Sciences in 1666. It does not suffice to restore the honor of creating the academies to Louis XIII and to Richelieu. We must go back as far as Conrart. The first, according to date, the French Academy, is, like many great institutions, due to private initiative. Conrart was nobody; he never became anybody. He is famous only by his silence, a kind of fame specially created for him by Boileau. It was he who first conceived the idea of making rules for a company of men who met by turns at the different members' houses to discuss literature. There were nine men in this company. "Insignificant men," said Voltaire in a disdainful tone. "Obscure men," he afterwards added, in speaking of the first academicians, twenty-eight in number, who received this title by letters patent from the King in 1635. Of course a Corneille or a Racine was not to be had on the spot to introduce into the academy. We had to wait twelve years for Corneille, thirty-six years for Bossuet, thirty-seven for Racine, forty-nine for La Fontaine and Boileau. The academy adorned itself with great men very slowly. It was never to have forty great men at once. No assembly, no matter when it existed nor to what nation it belonged, can ever have at one time more than a limited number of great men. Those whom Voltaire called insignificant men were perhaps not so insignificant as he thought them to be. They seem insignificant to

posterity, but they were great in the eyes of their contemporaries. Let us learn, if only for the sake of discretion, to respect superior men, even though they do not happen to be Voltaires nor Molières. We can not and we must not deceive ourselves with regard to men of genius; we may hesitate in our choice between men who are superior without being great, such as I shall call distinguished men above the average. It is an honor for the enlightened society of the seventeenth century that they at once attached great importance to this reunion of a few men of culture who occupied themselves neither with politics nor with religion, but confined their attention exclusively to literature and the products of the mind. This love of letters has remained one of the characteristic features of our national taste. From the time the public were admitted to the receptions of the French Academy they have flocked there. When it opened its doors on such days to women, in 1702, they also assembled there in crowds. The academy has been careful not to abandon this practice, which assumed in time great solemnity. A reception at the academy is emphatically a Parisian event. One must have been present, one must have formed an opinion of the two speeches, to appreciate it. Less importance is attached to the most heated discussions in the Legislative Assembly. The famous "coupole" becomes an instrument of torture: people are stifled there; some lose their consciousness. These fainting women add to the success of the two orators. They remind one of Spanish bull fights, which are only interesting in the eyes of their enemies when a "toreador" has been killed.

Cardinal Richelieu heard people speak of Conrart's Society, and having an instinct for what was great and permanent, he believed that this association might become an institution.

He offered Conrart's friends to give official recognition to the existence of their association, and this was about all he offered. "Honorable privileges," said Voltaire, "not one of them of any use; the founder procured for them not even a place of meeting."

In fact, he rendered the academy no other service than that of not ignoring it, but he thought, and everybody thought with him, that since he did not ignore it, he controlled it. Many of Conrart's friends hesitated. What they had looked for was liberty; instead, they were offered subordination. Their resistance could not be of long duration, however, for it was not customary to resist the King, nor the Cardinal, who was the King. To refuse a favor which they offered was more than resistance; it was disobedience. They yielded; they even offered thanks. They exalted the King and his great minister, Richelieu, who promised to protect them.

There was still another obstacle to the official creation of the academy. The Parliament also had a desire to resist. We know that registration was at that time necessary to give efficacy to royal decrees. Parliament could delay. It could make observations and even remonstrances.

Finally, however, it could, on great occasions, be brought to submission by a special court, called a "lit de justice." But they did not have recourse to such extremities in order to transform the reunions of Conrart into a royal academy, though Parliament showed its bad humor by the delay of a year. The Cardinal was compelled to make it understood, that he meant to be obeyed.

Efforts have been made to find out what caused this ill will on the part of the Parliament. It was not a question about the creation of a final court, but of "simple weighers of words," as they were called by the jokers of the time. The Parliament, according to Voltaire, feared that the academy would claim some jurisdiction over the library, and added this clause to the letters patent of the King: "The academy will only recognize the French language and such books as its members have written, or which have been submitted to its judgment."

I rather think that Parliament feared for the authority which it claimed for itself in religious and philosophical matters. The academy question touched the school question. The theological question was also in close proximity; the more the authority of the Parliament was contested in religious matters the more jealous it showed itself. They were guided in this whole matter by the same spirit which later suggested to them the reform of the university through President Roliand.

The King—and I speak here of Louis XV as well as of Louis XIV and Louis XIII—was constantly a good master to the academies, but a master nevertheless. The elections had to be submitted for his approbation. This is a right which had always been reserved for the public; it is still in existence in our day. Louis XIV exercised this power on a memorable occasion. He wished to have Boileau elected; the academy chose La Fontaine. The King refused his approbation. The academy therefore hastened to elect Boileau to the first vacancy. "Now," said the King, "you may proceed to receive La Fontaine."

The King also at times interfered with the work of the academy, but only on very rare occasions. It was he, or rather it was Richelieu, the author of the tragedy of Mirame, who prescribed that examination of the "Cid" which was contrived to exalt the glory of the Cardinal, and the result of which was to show the glory of Corneille in all its splendor. Voltaire, in the following century, under the pretext of impartiality and by mixing apotheosis with criticism, attempted the same undertaking and arrived at the same result.

The academicians for a moment turned aside from their more peaceable work and came back to the dictionary. During the revolution they did not escape reproach for having produced neither the grammar nor that art of poetry which the King expected from them, and for having carried on the preparation of the dictionary much too slowly. The academy was not so much to blame, though, as it was believed to be. Of the three objects confided to its care it had chosen the dictionary, which rendered to the language the double service of fixing its

terms and of explaining its rules by examples borrowed from the best writers. The dictionary advanced slowly, it is true, but this very slowness constituted its strength. The various readings which it recorded were all judged and adapted to the times before receiving official confirmation.

The dictionary itself is the whole French Academy. To our language, essentially flexible and full of life, which readily adapts itself to the expression of every new sentiment and new thought, and which suffices, without neologisms, for the exposition and demonstration of scientific discoveries, it gives all the solidity and the majesty of the two languages which have successively formed the incarnation of Greece and of Rome.

Louis XIV was desirous that there should be a language of Louis XIV, as there had been a language of Pericles and a language of Augustus, and he claimed for himself the honor of this idea when he said: "The encouragement of letters and of fine arts, having always contributed to the splendor of nations, the late King, our revered lord and father, ordered the establishment of the French Academy in 1635, in order to bring language, eloquence, and poetry to that point of perfection which it has at last reached under our reign."

I am not disposed to insist; I simply state what Louis XIV thought and those who have ever since been called The Forty. Our admiration of our own masterpieces and our own language does not prevent us from admiring the glories of other nations. We took part in the centennial of Shakespeare; Goethe, Schiller, and Cervantes are popular in our schools. No one can ever enter without feelings of profound respect the church of Santa Croce in Florence, where around the cenotaph of Dante are collected the tombs of Galileo, of Michel Angelo, of Macchiavelli, of Alfieri, and of Cherubini.

The eighteenth century was constantly reproaching the academies, and above all the French Academy, which bore the larger part of these attacks because it had borne the larger share of glory, and also because the public could more easily follow its labors, for having elected mediocre men, and for having left men of genius outside its doors. I have in my mind two men who were not members of the French Academy, Descartes and Molière. Rousseau, whose name is sometimes mentioned in connection with the omissions of the academy, was a citizen of Geneva.

Two errors in a century and a half! Men, as a rule, do worse than that. The greater part of Descartes's works was written in Latin. The "Discours de la Méthode," which is one of the grand monuments of the French language, was known only to a small number of men of science. The great splendor of Descartes's name began only after his death, when it was at last understood that he had emancipated human reason. Molière's profession was against him. We would laugh nowadays, and with good reason, at such an objection. It was, however,

a serious one under Louis XIV. The "gentlemen upholsterers" and "valets de chambre" of the King would not have desired to be made members of the academy. I do not know what Molière himself would have thought of his election. People were then preservers of rank as we are now of propriety. It was necessary to compel Catinat to allow himself to be made a marshal of France. As to the other great men, whose absence the convention regretted so bitterly, they belonged to the category of those whom we styled a moment ago great men above the average. They were justly admired by their contemporaries, but posterity has the right to choose from among them. Dufresny, Raynal, Helvetius are great men the omission of whose names caused much indignation in 1793, but we of to-day would disapprove of it had they been elected by the academy.

Of all charges brought against the academy, the one most frequently made was its fawning upon the King. It was a society of courtiers who could have given lessons upon this subject to all the Dangeaus who ever existed, for was it not they who had offered a prize for the best answer to the question, "Which of all the King's virtues deserves the most praise?"

But this style and these sentiments no longer existed when Grégoire, reproaching his "good Fénelon" for having written a treatise on "the control over a King's conscience," added, "as if Kings had any conscience! One might as well write a dissertation on the gentleness of wild beasts."

The mistake which men blinded by passion make, is to wish always to form a judgment without taking into account the time and the surroundings. With all respect for the levelers of 1793, the liberal spirit which had manifested itself in the midst of the academy at the moment of its official creation continued during its whole existence. The members combined with it an admiration of the King the nature of which we do not understand. The academy saw France in the King. At that epoch of history one was powerful only on the condition of being dependent. It can not be doubted that the academies, surrounded by the monarchy with honors, had become little by little veritable aristocracies. They had in the eyes of the Republicans the double defect of being corporations, and privileged corporations, much tainted by their privileges. A practice, introduced by Colbert, or rather by l'Abbé Bignon, his nephew and his representative in the government of scientific societies, divided the academies of inscriptions, of sciences, and of letters into three classes of academicians—the honoraries, the pensioners, and the pupils; thus, this constituted a privilege within a privilege. The French Academy alone resisted energetically; it refused to suffer the affront of such a regulation. The French Academy, since its creation, had always had in its midst dukes, marshals, bishops, and magistrates of supreme courts. These great lords learned to treat men of letters as their equals; but at the same time these men of letters

learned to consider themselves great lords. They complimented each other in order to perfect themselves in their principal duty, which was to praise the King and his ministers. These compliments have become the speeches made at the reception of new members.

Voltaire was not lenient toward them. "All I can perceive in these fine speeches," he said, "is that the new member having assured them that his predecessor was a very great man, that Cardinal Richelieu was a very great man, Chancellor Séguier rather a great man, the director repeats the same thing and adds that the new member himself might also be a kind of a great man, and that for himself, the director, he does not overlook his own claims;" and further on: "The necessity of speaking, the embarrassment of having nothing to say, and the desire to appear clever, are three things calculated to make even the greatest of men appear ridiculous."

Could the convention suffer the existence of a body which spent its time in heralding the virtues of the kings, which was itself a privileged body, and which numbered among its members men invested with a double privilege? It was the aristocracy of the mind, but still an aristocracy. "La Montagne" and "La Plaine" were agreed to overthrow it. An event had, however, taken place toward the middle of the eighteenth century which might have modified the judgment of the revolutionists. Voltaire was admitted into the academy. The academicians had valiantly defended themselves. Voltaire was twice refused. Finally he was admitted, and from that day the academy belonged to him. He had already his newspaper, the Encyclopedia, and the Encyclopedia went with him into the academy, which was thus transformed by anticipation into a veritable academy of sciences, moral and political. He caused Dreclos, d'Alembert, Marmontel, Condillac, Morellet to be admitted, one after the other. He failed with Diderot. He complained bitterly, and with good reason, for though Diderot is not exactly an academical genius, he is still, beyond all doubt, a superior man.

Voltaire writes to the Abbé d'Olivet: "Do try, my dear master, to give us a real academician in the place of the Abbé de Saint-Cyr, and a savant in the place of the Abbé Salier. Why could we not have M. Diderot this time? You know that the academy should not be a seminary, neither should it be a court of peers. A few gold ornaments for our lyre are befitting, but the strings must be of catgut and they must be resonant."

Voltaire was not accustomed to be thwarted, and had taken his revenge. He had the main body of his army in the French Academy. He had Condorcet, d'Alembert, Fontenelle in the Academy of Sciences. The Academy of Inscriptions showed more resistance, but he made his way everywhere. He was the oracle of the "cercles des précieuses," whose influence had replaced the decreasing influence of the court. Mme. de Lambert, Mme. de Tencin, Mme. Du Deffant, Mlle. de

Lespinasse, Mme. Geoffrin, and Mme. Du Châtelet received their inspiration from him. He was the (intermittent) friend of the King of Prussia and the correspondent (and flatterer) of the great Catherine. He had treated Corneille with arrogance. He believed himself to be more pathetic than Racine. In philosophy he defied the clergy, whilst observing his Easter duties at Ferney and dedicating his "Mahomet" to the Pope.

Judging him at the present time we can not help seeing in him a precursor of the revolution. Voltaire and the whole army he commanded had, in fact, served revolutionary ideas, but they had thought they were invoking a good genius, and when they found themselves face to face with it (I speak of Voltaire's lieutenants, for he died in 1778), it seemed to them they had invoked the devil. They hesitated on the way and they became by this simple fact the greatest enemies of their former friends. We could here make a parody on that grand saying: "There is more rejoicing in heaven over one sinner that repenteth - - - " and say: "There is more wrath in the revolutionary arm y over a friend who stops on the road - - - ."

The academies, whose services were forgotten, shared the fate of the parliaments and of the clergy. Grégoire, in a ridiculously emphatic report, proposed the suppression of the academies, at the same time asking that "from amid the ruins" the sanctuary of arts, rising under the auspices of liberty, should represent the organized reunion of all the scientists and all the means of science. "After to morrow," he said, "the French Republic will make its entrance into the world. On that day, on which the sun will shine upon a single nation of brothers, there should no longer be found on French soil any institution which might detract from the eternal principles which we have consecrated; and yet some which still bear the stamp of despotism, or have an organization incompatible with equality, have escaped the general rule: These are the academies."

Two years after having disbanded the academies in this polite manner the convention did a great thing—a very great thing. It reestablished them, and in so doing it subjected them to a thorough modification. The dream of one unique assembly of all scholars and artists, of poets and philosophers, already conceived by the Constituent Assembly, became a reality. Never had the fraternity of letters, sciences, and arts been affirmed with such emphasis. The new institution united in one body all the forces of passion and of thought. It created above the ordinary society, occupied with the cares of life, a sort of special world, which should unceasingly send forth new truths and masterpieces, in order to enlighten humanity and to fortify and charm it. The institute should take no part in the Government; it was not to be burdened with teaching. Its work was to be of a higher nature, it was to teach by example. In the same way that the God of Aristotle moved without being moved, and could ignore the world to

which he had given life, it is sufficient for scientists and poets to exist and to be known. Their works produce the movement, and at the same time they regulate it by the admiration which they inspire. Dannou, speaking in the name of the convention, said: "We have borrowed from Talleyrand and from Condorcet the plan of a national institute, a grand and majestic idea, the execution of which is to surpass in splendor all the academies of the Kings. - - - . This will be, in a way, the abridgment of the scientific world, the representative body of the republic of letters, a national temple, the doors of which, closed forever to intrigue, will open only at the arrival of genuine renown."

This union, sublime and productive of all that is eternal in sentiment and thought, is not the only grand feature of the new institution. The academies so far have been purely local. They recruited themselves from a single city and represented the scientific or literary movement of the city where they were born. But the institute, created in 1795 to replace the academies, is not a Parisian institute; it is a national institute, it is the Institute of France. The constitution of the year 3, the formula of which is faithfully reproduced by the constitution of the year 8, declares it in these solemn words: "There is for the whole Republic one single national institute, charged with collecting discoveries and with perfecting the arts and the sciences." Could I forget, in the sight of this assembly, that the national convention opened the doors of the institute, not only to all men of French nationality, but to all great men, whatsoever be their origin? Just as Louis XIV rewarded genius, no matter to what nation it belonged, the convention also created within the institute the order of Foreign Associates, which permits us to inscribe on our lists of honor Huyghens, Newton, Leibnitz, and, nearer home, Rossini and Meyerbeer.

The work of the convention is, therefore, not the re-creation of the former academies, disguised under new names and modified in secondary details of their organization. It is in fact a new work. It is a creation, a powerful creation. It is the Academy of France, representing at the same time sciences, letters, and arts. It contains the former academies, but inclosing them in a new and strong synthesis. It is our right and our duty on this day of rejoicing to offer our homage alike to the old academies which prepared the institute and to the institute which contains and completes the former academies. The work of the convention is grand enough to enable us to acknowledge that the Assembly had been less happy in the details of execution than in the first conception. It had exaggerated everything; its own authority over the institute, and the authority of the institute over the members who compose it. It did not know what liberty meant. It said, as Louis XIV did: L'état c'est moi! and when it had usurped all power it said: "Now we are free!"

The first fault of the convention, in this as in many other things, was

its immoderate love for sweeping destruction. It suppressed the academies, which it might have modified while preserving them. It even suppressed their names in the reorganization which it undertook afterwards. It has been said with truth that it was afraid of words. It replaced those illustrious names by common appellations of first, second, and third class, and yet succeeded by these changes only in veiling all historic associations. It effaced another name which should have been particularly sacred to it. Having to place philosophy in the class of sciences, moral and political, which it was organizing for the first time, it replaced this name, which might have suggested spiritualistic beliefs, by that of analysis of sensations and of ideas, which recalls only Condillac. Chaptal, who, already in 1801, reproached the organization of the institute with "having gone much too far away from what experience had proved to be perfection in the composition of our old academies," made in 1803 a new plan in which he showed himself more just and more able than the convention. He even proposed to restore the names of the old academies, on which France had prided herself for more than a century and which had become the model of the literary and scientific institutions formed successively in all parts of Europe. The council of state would not consent. It approved of the bulk of the proposition, but it did not restore the names of the old academies.

The Academy of Moral and Political Sciences, founded for the first time in 1795, and which formed the second class of the institute, had a short existence. The First Consul had one day said to M. de Ségur: "You preside over the second class of the institute. I command you to tell them that I do not wish to have politics discussed at their meetings. If the class disobey I shall abolish it as a bad club." True to the end to his aversion for those whom he styled ideologists, when he proceeded with the reorganization of the institute in 1803, he suppressed the second class by silence, suppressing its name and distributing the members among the other classes.

The first mistake of the convention was then to give up venerable names and an illustrious past; it made another mistake in the mode of election which it adopted. The candidates were presented by the class in which a vacancy occurred, and the institute as a body was charged with choosing from among the candidates thus presented. Never before had fitness been treated with such contempt. An actor decided the election of a mathematician. A painter judged a philosopher. Here was an assembly which admitted Jews among the voters for the election of Catholic bishops. Election by class or academy was only established in the year 11 upon a report made by Chaptal.

The convention committed another error. The effect of the two first was to exaggerate unity, the third exaggerated and misrepresented the national character of the institute. It was the institute of France, and they wished it on that account to be composed partly of Parisians and partly of provincials. It would have been sufficient to say that

men of the first merit could be elected, whether they resided in Paris or elsewhere. No, it seemed to be more radical to divide by halves. This even ceased to be just, because Paris had a population of only 500,000 inhabitants and the provinces counted 25,000,000, and this was not reasonable, since a man of eminence might desire to live in Paris because of the libraries, the museum, the amphitheaters, and all the other means of study there. A section of the dramatic art had been admitted; three Parisian actors, three provincial actors. Everyone is aware that, although great actors may have their beginning in the provinces, they can not remain there where they have neither traditions, nor schools, nor the auxiliaries, nor the public which they need, nor material resources. As much may be said of scholars and of artists. The residence rule was very strict then, much more so than it has been since. A member nominated to represent Paris, and who took up his residence definitely in the provinces, was forced to send in his resignation. Destrutt de Tracy, who lived at Auteuil, was nominated a nonresident member. The greatest error committed perhaps is the inside regulation of work, which was imposed by organic decree. The Government claimed in this regulation the right to request the opinion of the classes of the institute. It was especially to the Academy of Sciences that it addressed these demands. It consulted it on the subject of covered conveyances destined for the removal of the sick, on the improvements to be made in hospital regulations, on the monetary system, on a way of reconciling the era of the Republic with the common era, on a new kind of cannon ball, on an oiled taffeta suitable for making cloaks for the troops, on the idea of placing several rows of guns on a common frame, on the preservation of drinking water on board ship, on the preservation of biscuits and of vegetables at sea. There were also questions for the other classes, even philosophical questions, which tended to make a state doctrine. Nothing is more hostile to philosophy and to true policy, and nothing can impede more seriously the progress of science and the splendor of academies. In a well organized literary body, the authority of each member grows with that of the association, but on condition that there shall result from it no intermeddling by the Government, nor by the academy, with the individual labor. When General Cavaignac, to refute the socialists of 1848, asked the Academy of Moral and Political Sciences to write some popular pamphlets on the subject, the academy failed to do it—we must frankly confess it—although it had appealed to the greatest men of science. A great mind is not found in work done on demand. Genius must breathe the air of liberty.

This right of requisition did not appertain to the Government alone: it belonged also to the public. Every author could demand an analysis of his book, every inventor an examination of his discovery. Thus, the academicians were no longer masters of their own time. I am no longer astonished at their being assigned two costumes, one for ceremonious

occasions, and one to work in. No one seemed to see that being bound to serve everybody they had no longer time to serve science.

I do not wish to enumerate all. I shall, however, mention the suppression of the perpetual secretaries who were replaced by two secretaries, elected semiannually. This was taking from the academies their unity, their life. Chaptal, in 1801, speaking of the old academies, said: "The same man followed all the details of the academy, became its historian, and connected in a very peculiar manner the glory of his name with that of the body, whose organ he was. There was more consistency in the administration, greater celerity in the execution, and it can not be denied that the reestablishment of a perpetual secretary for each class of the institute, by opening a career which presents so many great men as models, would contribute to the glory of this body and to the progress of science." And later, in 1803, he returned to the charge. "The reestablishment of these places," he says, speaking of the perpetual secretaryships, "will revive a branch of eloquence which has been very much neglected for the last ten years, and will give to academical labors that spirit of order, that combination of facts with thoughts, which alone can precisely fix the dates of discoveries and trace with accuracy the history of human knowledge."

Although declaring that it renounced the academical past, the convention, by the very force of circumstances, had preserved for its institute all the advantages which the old academies enjoyed. It retained the recognition of the institute by the state, and the intervention of the state in interior regulations. It left to the institute the home of the academies, the library, the participation in the nomination of professors in the great literary and scientific establishments. The institute has carefully preserved this prerogative, and still presents candidates for the College of France, the Museum, the Academy, the schools of Rome and of Athens, the School of Maps, the School of Living Oriental Languages, the Conservatory of Arts and Handicrafts, the Observatory, the Polytechnic School. It has preserved the gratuitous copies and the prizes known as prix du budget, to which are now added certain prizes founded by private initiative, the annual amount of which does not fall much short of 524,500 francs! On the 29th Messidor, year 4, the convention gave to each member of the institute an annual indemnity of 750 myriagrams of wheat, and on the 19th Thermidor following it decided that out of this indemnity there should be kept back, on account of each member, a sum equal to 150 myriagrams of wheat, to be distributed among those who had been present at the meetings, both general and special, in each class.

In 1803, upon a report made by Chaptal, the members of this institute were permitted to belong to several academies at once, and in consequence to combine several indemnities. "This gives us," said Chaptal, "the means of opening to men of distinction many avenues to glory and to comfort, and in consequence the means of multiplying

and promoting talent." The right of accumulating academies still exists, but that of accumulating indemnities has been done away with. We are still at the 750 myriagrams. Those among us who belong to several academies receive only one indemnity. We boast of not being rich. The members of the institute, when 750 myriagrams of wheat, or, to speak more intelligibly, 1,500 francs, were fixed as the indemnity which was to relieve them of all cares of life, never imagined in their most ambitious dreams that they would possess one of these days one of the most beautiful palaces in the world, with a picture gallery, a library created all at once by the gift of a great writer and doubled by an eminent scholar, woods, lakes, and a whole world of beautiful souvenirs.

It would perhaps be well to recall here the fact, in order to explain both our wealth and our poverty, that all gifts made to the institute are made to science or to the poor. The members of the institute never profit by them. A new donation is for them only an increase of labor. The Emperor Napoleon III wished one day to raise the indemnity from 1,500 francs to 5,000, which made a very respectable quantity of wheat. The institute, however, upon being consulted expressed its gratitude and refused.

It has sometimes been remarked that all the efforts of the revolution to transform the academies were after all but illusory. On the 8th of August, 1793, they are suppressed—on the 25th of October, 1795, they are replaced by the institute. It was almost immediately perceived that this institute, just because it was new, was not likely to live. From 1803 they commence to reform it; the reforms are multiplied from year to year, and to what did they lead? To suppressing the greater part of the innovations, to restoring the old academies, and even, in 1826, to giving them back their names. Those that speak thus do not see that there remains to the revolution the glory of having established a close bond between the academies, of having appreciated the solidarity of letters, sciences and arts, of having put the academies in more intimate communication with the public, and of having given them new and serious means of influence.

From the ancient associations and the rearranging of the new ones resulted the present institute, in which the protection of the state does not exclude the liberty of the members, where each one is alone responsible for his own doctrine, where solidarity of honor, which unites all the members, makes eccentricities impossible, where all the members united, without losing their identity, lend each other mutual assistance and yet never fall into confusion, where all the work done tends to the manifestation of truth and to the triumph of art—a body, in fine, which unites in just proportions, authority and liberty, and which deserves to be held up as a model to all civilized nations.

I venture to add, gentlemen, that your presence here, that of the respected chief of the nation, and the splendor which is the result, will give to the Institute of France a new consecration.

The world for the past twenty-five years has been witnessing a curious spectacle. On one hand the governments are multiplying with a sort of rage preparations for war. They are building fortresses, they are casting guns, they are filling their arsenals with projectiles. Military service in the active army is required of all young men without exception to the extent of emptying the schools and of disorganizing public and private service, of taking from agriculture and industry the arms which they need. They retain all citizens in the bonds of military service until their forty-fifth year. It looks as if the battle were to be fought to-morrow.

At the same time all philosophers and publicists, all statesmen and the sovereigns themselves, protest in loud tones their horror of war. They want peace. They must have it to give to labor security, to intelligence its rights. and to the year its spring. Leagues for the maintenance of peace are formed on all sides, congresses are convened to protest against "armed peace," which is more ruinous and more murderous than war.

Alas! These congresses bring nothing but good wishes! That is a great deal, and yet it is nothing. They bring good wishes, and I dare not say that they bring hopes! What mankind needs is not words, nor does it need sighs. It needs acts. What will revive true fraternity between men is great works done in common, and great services done to humanity.

Here you have before your eyes the true Congress of Peace! This is the congress where Truth is beloved for its own sake, no matter in what country it comes to light, where poetry is worshiped in all languages, where great discoveries call forth the same enthusiasm, no matter what may be their origin, and where no other emulation is known save that of doing well. The land of eternal truth and of eternal beauty is also the land of peace.

Associates and correspondents of the Institute of France, you will carry away with you not only the remembrance of the warm sympathies which welcomed you here, we shall all of us carry away from this fraternal reunion an increased love of peace, of the sciences which make it bear fruit, and of the arts which embellish it. And we shall labor, each one of us in his chosen corner of the universal workshop, for the prosperity of the house—that is to say, for the happiness of mankind.

SCIENCE IN EARLY ENGLAND.[1]

By Charles L. Barnes, M. A., F. C. S.

Under the ample shelter afforded by the words "literary" and "philosophical," I feel that a paper on the progress of science in England from the seventh to the thirteenth century, inclusive, may find admittance, though that which is new, and not that which is old, is more usually welcomed within these walls.

The authorities from whom my remarks have been gathered are, in the main, as follows:

(1) Popular Treatises on Science, written during the Middle Ages in Anglo-Norman, Anglo-Saxon, and English, edited by Thomas Wright, and published for the Historical Society of Science, 1841. This society, whose existence seems to have been forgotten, had for president the Duke of Sussex, and for vice-presidents, the Earl of Munster, Lord Holland, the Bishop of Durham, and three others, while several distinguished names appear on the council, viz, Augustus de Morgan, J. O. Halliwell, Sir Francis Palgrave, the Rev. Robert Willis, professor of natural experimental philosophy at Cambridge, Thomas Wright, and several more. Another of its publications, also issued in 1841, has the following title: A Collection of Letters illustrative of the Progress of Science in England from the Reign of Elizabeth to that of Charles II, and is edited by Halliwell, afterwards better known as Halliwell Phillips. A further list of books in contemplation is given in each of these volumes, but they are not to be found at the reference library, and I have not yet been able to discover when or why the society dissolved, unless it died a natural death on the publication of the Rolls series.

(2) Biographia Britannica Literaria, by Thomas Wright. Two volumes. Published for the Royal Society of Literature, 1842.

(3) Alexander Neckam, De Naturis Rerum, edited by T. Wright. 1863. Rolls series.

(4) Leechdoms, Wort-cunning, and Starcraft of Early England, edited by the Rev. Oswald Cockayne. Three volumes. 1866. Rolls series.

[1] From Memoirs and proceedings of the Manchester Literary and Philosophical Society, Fourth Series, Vol. X, No. 1, 1895–96.

(5) Roger Bacon, Opus Minus, Opus Tertium, and Compendium Philosophiæ, edited by J. S. Brewer. 1859. Also in the Rolls series.

Many fragments have also been gleaned from the Encyclopædia Britannica and the Dictionary of National Biography.

This country, in its earlier days, lay quite outside the sphere of scientific influence; remote from Egypt, Rome, or Greece, and the arena of constant struggles between the native races and their invaders, it offered more attractions to warriors and missionaries than to philosophers, consequently we may pass over not only the whole Roman period, but a considerable interval after the invasion of the Saxons in 449, without finding a single circumstance to dwell upon. The conversion of this people to Christianity was begun in 597 by Augustine, at the instance of Pope Gregory the Great, and the intellectual awakening which followed from this event soon bore fruit in the development of the language and literature. The poems of Cædmon, Cynewulf, and the legendary Beowulf are the earliest specimens of Anglo-Saxon achievements in a most difficult art, and date from 660 to 700 or thereabouts.

In the eighth century the cultivation of letters was taken up even by women, many of whom wrote Latin and French with equal ease, while all ranks were in the habit of making journeys to Rome, whence they returned laden with books and ideas which they did their best to disseminate.

The want of Anglo-Saxon scientific terms delayed the translation of books into the vernacular, and those which existed in any language suffered severely between the ninth and eleventh centuries at the hands of the Danes, and in a minor degree from an unfortunate custom of scraping the letters off old MSS. to make room for new matter.

The barbarous Northmen, who have been described as the curse of England at that period, were especially bitter against monasteries and the treasures they contained, and from the sacking of Lindisfarne or Holy Island in 793 till the reign of Canute did incalculable damage. Under this monarch, himself a Dane, the country had a temporary prosperity. After him came the English restoration, then the Norman Conquest, and so on. At no time were the sword and implements of war laid by for long, and those whose bent would have been toward philosophy under happier circumstances were forced to keep silence or to fall in with the popular current. These things must be borne in mind before we judge our ancestors too harshly. It is well known that the Saxons made furnaces for the evaporation of salt in Cheshire and Worcestershire, and contrived dishes of metal and even of transparent glass for domestic purposes, while their agriculture was conducted upon sound principles, though with rude instruments.

The sources of their scientific information were, in the first place, Greek and Roman; but as they accepted without question the authority of Aristotle and Pliny, they made no advance worth speaking of till

the eleventh century. Much progress had long before been made in other countries. The great Alexandrian school—the closing scene of which was the murder of Hypatia in 414—had been continued for two centuries in Persia; thence it was carried by the Arab conquerors into Spain, and flourished abundantly from the ninth century onward at Granada, Cordova, Toledo, Seville, and elsewhere; but owing to the lack of travelers sufficiently versed in Arabic, and at the same time capable of assimilating the new ideas, their diffusion into England took place very slowly. The philosopher's stone and potable gold, the elixir of life, were undreamed of till the Arabian influence was felt, and chemistry and medicine were in a state of which the less said the better.

Of those who endeavored to keep alight the flame of science in this country were, in the first place, Bede, the monk of Jarrow (672–735), styled in after times the Venerable, the Father of English learning, whose work, De Natura Rerum, served as as a foundation for other writers for a long period, though it only represents a very small part of his literary labors. It is chiefly a cosmography and cosmogony, the same which had prevailed in Europe for many centuries. The earth was the center of the universe, and the firmament a sphere, bounded by fire; beyond this was heaven, the abode of angelic natures, capable of human and superhuman functions. The planets were seven in number and revolved within the firmament; comets were stars suddenly developed, which portended pestilence, revolution, war, or tempest; lightning was produced by the collision of clouds, just as fire is produced by striking two flints. This idea is to be found in Lucretius, first century B. C., in Book VI, De Rerum Natura: "It lightens then, when the clouds have struck out by their collision many seeds of fire, just as if a stone were to strike another stone or a piece of iron, for then, too, light bursts out and fire scatters about bright sparks." Probably the same notion had been current for untold ages before this.

Two other works of Bede's were written to elucidate questions connected with Easter, this feast having at all times presented problems of a most thorny kind. Characteristically enough, Bede believed that the world in his day was old, decrepid, worn out, and in its sixth stage, and that it would shortly come to an end.

Toward the end of the seventh century (in 668, to be very precise), Theodore, a native of Tarsus, was made Archbishop of Canterbury, and taught astronomy and arithmetic in the schools, while Albert, Archbishop of York, also diffused the higher branches of knowledge. Under the system of the schools, learning was divided into seven arts, the "Trivium," comprising grammar, logic, and rhetoric, and the "Quadrivium," namely, arithmetic, geometry (probably mensuration or surveying, not Euclidean geometry), astronomy, and music. The number of arts was, however, sometimes expanded to ten by the inclusion of astrology, medicine, and mechanics, though these occasionally replace grammar, logic, and rhetoric, instead of supplementing them.

After these we have Gerbert, born about 950, better known in later

times as Pope Sylvester II, and his followers, Elthelwold of Winchester (925–984), and Dunstan of Glastonbury (925–988), the latter of whom subsequently became Archbishop of Canterbury. Gerbert, though not an Englishman, may be introduced as having made Europeans acquainted with the Indian numerals and algebra, and with various mechanical inventions, such as the clock pendulum. He had studied at Cordova and Toledo, and acquired a great reputation, not unmixed with obloquy as a dabbler in forbidden arts. Ethelwold was famed as an ingenious mechanic, and a treatise by him on the quadrature of the circle is in existence at the Bodleian Library. Dunstan fell under the same imputation as Gerbert, and is recorded to have possessed a magic harp which played sweet tunes by itself when hanging on a wall. He once survived the ordeal of being thrown into a pond. His favorite studies were arithmetic, geometry, and music, and a story of him in connection with a pair of tongs and a forge has caught the popular ear.

Ailmer, a monk of Glastonbury, is credited with the manufacture of a pair of wings wherewith to spurn the ground. He broke his leg on coming down too roughly after an attempt to fly from a church tower, but, with a true scientific spirit, attributed his misfortune to the want of a tail to the machine.

Robert, Bishop of Hereford (died 1095), wrote on the motion of the stars and the lunar computus (a method of finding Easter). He also compiled a number of mathematical tables.

Next we find Athelard of Bath, whose name is said to be the greatest in English science up to the days of Grosseteste and Roger Bacon. He traveled in Greece, Spain, North Africa, Sicily, and probably to Bagdad, then one of the chief seats of Arabian learning, and translated Euclid from Arabic to Latin, thus introducing a text-book which still survives amongst us. (A version in the same tongue taken direct from the Greek is said to have been made by Bœtius, who lived from 475 to 525, but his writings were not read till late in the Anglo-Saxon period.) Later on, somewhere between 1110 and 1120, he founded a school in France, where he taught the then new and unpopular sciences he had learned.

Philippe de Thaun, writer of a Bestiary, to be noticed presently; William of Newbury, who gave currency to the fables of animals embedded in rocks surviving their accidental release, and to legends of dragons and other monstrous creatures (probably founded on fossil bones); Alexander Neckam (1157–1217); Grosseteste, Bishop of Lincoln (died 1253), and Roger Bacon completed a list, which is only meant to include the principal names. Of Neckam and Bacon, I shall have more to say presently. Grosseteste has been favorably noticed by George Boole as having had a glimpse of the principle of least action. Starting with a datum derived from Aristotle, that there is greater union and unity in a straight line than any other, and assuming that all united virtue is more powerful than that which is not united, he deduces that nature, operating in straight lines, operates in the best manner

possible. Hence he infers that light travels in straight lines, and gives the law of reflection correctly, but accounts for refraction by hinting that the ray is less weakened by this process than the other. He might have learned all his optics and more from Euclid and Ptolemy.

Now, quitting the list of authors, we may glance at some of their works, taking here and there an extract where the quaintness or interest appears to demand it.

Among the arithmetical problems in vogue we have the following: "The swallow once invited the snail to dinner; he lived just one league from the spot, and the snail traveled at the rate of an inch a day. How long would it be before he dined?" This problem casts an unworthy slur upon the powers of locomotion possessed by the gasteropod, and even upon his intelligence, though it does not specifically say that the swallow's invitation was accepted. Here is another, which has been battered to and fro throughout the centuries, but which is still recognizable as an old friend: "Three men and their wives came to the side of a river, where they found but one boat capable of carrying over only two persons at once. All the men were jealous of each other. How must they contrive so that no one should be left in company with his neighbor's wife?" A third instance shows that the arithmetical bogey of school books, who, when asked a straightforward question, answers it in the most crooked way he can think of—stretches his line far back. "An old man met a child. 'Good day, my son,' says he, 'may you live as long as you have lived and as much more, and thrice as much as all this, and if God give you one year in addition to the others, you will be just a century old.' What was the lad's age?" To prevent a needless waste of exertion, I hasten to say that he was eleven. These problems were current in the tenth and eleventh centuries.

Some sciences were taught by dialogue, never a good method even in our day, but it might have been given up earlier with advantage if the following are fair samples. To the question, "Where does the sun shine at night?" The answer is returned that "It shines in three places: First in the belly of the whale called leviathan, next it shines in hell, and afterwards on the island called Glith, where the souls of holy men rest till doomsday."

Q. Where is a man's soul?—A. In his head, and it comes out at his mouth.

Q. Where resteth the soul of a man when his body sleepeth?—A. I tell thee it is in three places—in the brain, the heart, and the blood.

Occasionally they degenerate into riddles: Q. What is that from which if you take the head it becomes higher?—A. Go to your bed and you will find it.[1]

The "Popular Treatise on Science," above mentioned, comprise: (1) A tract on astronomy in Anglo-Saxon, abridged from Bede's De Natura Rerum, by an unknown author, probably about 990. (2) The Livre des Créatures, by Philippe de Thaun. (3) The Bestiary, by the

[1] The head of the occupier is that which becomes higher.

same author, in Anglo-Norman, about 1120. (4) A fragment on science from the Metrical Lives of the Saints, about 1250, in English.

In the astronomical treatise we find, of the sun, that "she is ever running about the earth, and so light shines under the earth by night as it does above our heads by day. On the other side where she shines there is day, and on the side where she does not shine there is night." Further on we read: "Every day the moon's light is waning or waxing four points through the sun's light, and he goes either to the sun or from the sun so many points. Not that he arrives at the sun, for the sun is much more elevated than the moon. It happens sometimes when the moon runs on the same track that the sun runs, that his orb intercepts the sun so much that she is all darkened, and the stars appear as if by night. This happens seldom, and never but at new moon." This partition of genders, still remaining in modern German, is also found in old Norse, Arabic, Sanskrit, Hebrew, etc., but not in the Latin or Neo-Latin tongues. It is quite indefensible on optical grounds, as the feminine quality, that of giving back after it has received, is nowhere more clearly indicated than in the case of our lesser light. But to proceed: "The sea and the moon agree between them; ever they are companions in increase and in waning, and as the moon daily rises four points later than he did before, so also the sea flows always four points later." The origin of rain, hail, and snow is given sensibly enough, but on thunder the writer is rather vague. "It comes of heat and moisture; they strive with each other with a fearful noise, and the fire bursts out through lightning and injures the produce of the earth if it be greater than the moisture. If the moisture be greater than the fire, then it does good."

The second treatise, the Livre des Créatures, or book of created things, is in verse and comprises 1,588 lines. It deals with the signs of the zodiac, the days of the week, lunations, epacts, the finding of Easter, and so on. It appears to have no great value beyond its historic interest, as many of the derivations are fantastic and misleading. For example, the writer says that "September, October, November, and December were called rains, for then there are tempests, that is in Latin *imber*, from which is derived September, and the three others are derived thus." Modern philologists are content to derive these names from the Latin numerals, septem, octo, etc., and Chambers adds that the final syllable comes from the Persian word *bar*, meaning a period of time. The book goes on to say that February was the month which Pluto had, because he caused no incumbrance to the soul when he went to hell. One does not see the connection here; in any case, the matter is more clearly expressed in our dictionaries, according to which February is the month of expiation, after a Roman custom. With May and June he is again not easily reconcilable with the moderns, as he derives one from the elders or *majores*, the other from the juniors. We connect them both with words which signify growth.

In the signs of the zodiac he sometimes touches on delicate ground.

"Cancer signifies that it can not go straight by land nor by sea, and when God came on the earth to conquer our souls He went much from side to side; He dared not come forwards, He feared much to Pagans and the Jews, because they were to kill Him and make Him a martyr." "The fifth sign is placed in July, which is called Lion, because he is very great before and his legs are feeble behind; so the sun in the beginning takes all his force; he is all boiling, very hot and burning; when he is come to the middle he has hardly more strength than the lion who has small flanks."

We must now leave this treatise and proceed with the Bestiary. This particular one was written for the instruction of Adelaide of Louvain, Queen of Henry I, to whom she was married in 1121; but works on natural history, compiled from Greek and Roman writers, were common under the name of Physiologus or Bestiary, from the tenth or eleventh century onwards; copies being known in Old High German, Icelandic. Provencal. Arabic, Syriac, etc., not to mention Latin and French. Many strange qualities are assigned to real beasts in this compilation, and stranger still to the fabulous ones "Cetus is a very great beast; it lives always in the sea; it takes to sand of the sea, spreads it on its back, raises itself up, and will be in tranquillity. The seafarer comes, thinks that it is an island, and goes to arrive there to prepare his meal. The whale feels the fire and the ship and the people, then he will plunge if he can and drown them. This cetus is the devil, the sea is the world, and the sands are the riches of the world; the soul the steersman, and the body the ship which he ought to keep, and the fire is love, because man loveth his gold, his gold and his silver. When he perceives that and he shall be the more sure, then he will drown him. And this cetus, says the writing, has such a nature that when he wants to eat, he begins to gape, and the gaping of his mouth sends forth a smell so sweet and so good, that the little fish, who like the smell, will enter his mouth, and then he will kill them, then he will swallow them, and similarly the devil will strangle the people who shall love him so much that they will enter into his mouth." Hardly a single one of these descriptions is allowed to pass without a moral, the constant repetition of which becomes wearisome, not to say exasperating, to a modern reader, as it probably did to the ancient one. The salamander is of course found here. "If it come by chance where there shall be burning fire, it will immediately extinguish it; the beast is so cold and also of such a quality, fire will not be able to go where it shall enter." Also the wild ass which brays twelve times both by night and day at the equinox; the beaver with a curious instinct, and the serra with the head of a lion and tail of a fish, which, when it sees a ship, rises up and keeps the wind off it. It is somewhat startling to read that "the turtle is a bird, simple, chaste, and fair, and loves its mate so much that never during its life will it have another. Always afterwards it will lament him; nor will it be any more on the branch." One's appreciation of what appears at first sight an amazing blunder

is, however, spoilt by the reflection that turtle here is the French tourterelle, and is more familar as turtle dove. Here is also the adder which fears the voice of the enchanter, and to keep itself from harm closes one of its ears with its tail and presses the other to the ground; the eagle which, when its eyes are dim and its wings can no longer carry it, flies to the highest regions of the sky, and when the sun has burnt its wings and blinded its sight falls into a fountain, plunges therein three times, and is revived; and many more too numerous to mention. The fable of the adder stopping its ears is of great antiquity, being alluded to in Psalms, lviii, 4 and 5: "They are like the deaf adder that stoppeth her ear; which will not harken to the voice of charmers, charming never so wisely." Again, in Psalms ciii, 5, the words, "So that thy youth is renewed like the eagle's," give at least an equal antiquity to the other one.

In the "Leechdoms, Wort cunning, and Starcraft of Early England" we are struck by the quaint Anglo-Saxon expressions for medicine, botany, and astronomy, while at the same time we recognize that the difficulty of translating scientific works into the vernacular must have been very great. The Leech book, dating from 900 to 950, is compiled from Greek and Roman, as well as from Eastern and Scandinavian sources. In it an ache or pain is usually called "wark," a word which has survived to our own day in the dialect of this country, with only a slight change. "For tooth wark, burn white salt and garlic, make them smoke on glades (ashes), roast and tear to pieces, add pepper and clubmoss, and lay on." No inconvenience is too slight to find a remedy here. "Against a woman's chatter, taste at night fasting a root of radish; that day the chatter can not harm thee." Is a man weary and ill at ease, "he may eat radish with salt and vinegar, soon the world will be more gay."

Empiricism and superstition have about equal share in the book, e. g., for a remedy to be efficacious a plant must be gathered in a certain month when the moon is on the wane, or it must be dug up without iron, and so on. Time, and not material, prevents any more quotations in this place.

In the Wort-cunning, many valuable qualities are ascribed to plants, which, in our degenerate days, are utterly neglected. Of feverfuge, we are told that "This wort, which is named Centaurea minor, and which some call the lesser churmel, is produced on solid lands and on strong ones. Also it is said that Chiron the Centaur found these worts, whence they obtained the name of Centaurea. For bite of snake take dust of this same wort or itself pounded, administer to the patient in old wine, and it will produce much benefit. For sore of eyes take this same wort's juice, smear the eyes therewith; it heals the thinness of the sight;" and so on for many, many pages. The Starcraft in this book is the same as that given by Wright in the Popular Treatises, and has been already quoted from.

We must now glance for a moment at Alexander Neckam. Born at

St. Albans in 1157, he migrated to France at an early age, and obtained a professorship at Paris in 1180, but in a few years returned to England. He applied for admission to the great Benedictine Monastery of his native town, but tradition relates that a jocular reply of the abbot nettled him so much that he joined the Augustinians at Cirencester instead. The reply was as follows: "Si bonus sis, venias; si nequam, nequaquam." "If you are a good man, you may come; if you are a bad one (a Neckam), we won't have you at any price."

He composed a Latin elegiac poem on science in ten books, but his principal work is De Naturis Rerum, which was written before the end of the twelfth century. It includes an account of the creation, and dissertations on the four elements, on astronomy, natural history, and on minerals. The earliest recorded mention of the man in the moon occurs here, though only as a tradition; the marks on its surface are ascribed to caves, hills, and valleys. His remarks on magnetism are worth quoting, as he is the first English writer who mentions this subject. After explaining the hanging of Mahomet's coffin by this means, he continues: "The sailors, moreover, as they sail over the sea, when in cloudy weather they can no longer profit by the light of the sun, and when the world is wrapped up in the darkness of the shades of night, and they are ignorant to what point of the compass their ship's course is directed, they touch the magnet with a needle, which is whirled round until, when its motion ceases, its point looks direct toward the north." In another treatise, De Utilitensibus, also of the twelfty century, he has another mention of the compass, and says that "among the stores of a ship there must be a needle mounted on a pivot, which will oscillate and turn till the point looks toward the north." The pivot is a distinct advance over a needle floating on a straw. In view of the interest attaching to early references to the compass, I may quote the following extracts, given for the sake of reference, in the same volume. Cardinal Jacques de Vitry, Bishop of Acon, in Palestine, in a history of Jerusalem, written about 1218, says: "An iron needle, after having been in contact with the loadstone, turns itself always towards the north, which, like the axis of the firmament, remains immovable, while the others follow their course, so that it is very necessary to those who navigate the sea." Again, Guyot de Provence, in a love song of the early part of the thirteenth century has these lines:

> They know its position for their route,
> When the weather is completely without light,
> All those who employ this contrivance.
> Whoever trusts a needle of iron
> So that it remains almost entirely outside
> In a bit of cork, and rubs it on the brown loadstone
> If it be put in a vessel full of water
> So that nobody push it out.
> As soon as the water becomes quiet,
> To whatsoever side the point turns
> There is certainly the polar star.

Lastly, Dante's preceptor, Brunetto Latini, writing about 1260, just after a visit to Roger Bacon, says: "He shewed me the magnet, an ugly black stone to which iron spontaneously attaches itself. They touch it with a needle and thrust this into a straw, then put it in the water; it swims, and the point turns toward the polar star. If the night be dark, and one can see neither star nor moon, the mariners can keep their right course." Bacon is the only writer, as far as I know, who mentions magnetic repulsion, "as the lamb flees the wolf," he puts it.

Neckam's remarks on animals are of little interest, as they reflect all the popular errors. He is the only author, except Bacon and Grosseteste, who deals with optics. He describes the well-known basin and coin experiment (this, however, was known to Cleomedes in the first century A. D.), and speaks of glass mirrors. He tells us that in a concave mirror the image is inverted, and in a plane or convex one erect, but remarks despairingly, "Who can assign a sufficient reason for these things?" An interesting observation, which he might have learned from Eratosthenes, of the third century B. C., is that verticals to the earth's surface must be inclined to one another; he goes rather too far, however, and says that the walls of buildings must diverge, so as to be in the direction of the earth's radii. He notes that all ponderable things tend naturally toward the center.

Here, also, we find an interesting fable, that the wren, sitting on a branch on the 1st of March, complained to February about the mildness of the weather. She at length became abusive on the subject, whereupon he went to his brother March and obtained permission to influence the weather for two days. This he did with such effect that the bird, battered by hailstones and half frozen, lamented that the gentle February was past. It is well known to meteorologists that there are nearly always three cold days between the 11th and 14th of April, and that in the old style these dates would fall at the beginning of the month: but I am not aware that a converse state of things has been noted in March. The old Scotch rhyme which follows relates to the "borrowed" days of April:

> March said to Aperill,
> I see three hoggs upon a hill,
> And if you'll lends me dayes three,
> I'll find a way to make them dee.
> The first o' them was wind and wet;
> The second o' them was snaw and sleet;
> The third o' them was sic a freeze,
> It froze the birds' nests to the trees.
> When the three days were past and gane,
> The three silly hoggs came hirplin hame.

The word "hogg" here is a farmer's term for a young lamb between the time of its being weaned and having its first fleece cut.

In Roger Bacon, the last author with whom I shall deal, one feels

instinctively, after even casually turning over a few pages, that the style is vastly superior to and more scientific than anything that has gone before. There is a solidity and keenness of penetration about it which is sadly wanting in his predecessors, who were content to hand down what they had learned without so much as a show of criticism.

Roger Bacon was born at Ilchester, in Somersetshire, in 1214. He took the degree of doctor of theology in the University of Paris, famed in those days above Oxford, Salerno, or Montpellier, and acquired a mastery of the Latin, Greek, Hebrew, and Arabic literature of his time. He joined the Franciscan order of monks, but incurred much opposition from them, even to the extent of being thrown into prison on several occasions on account of having fallen under the suspicion of magic. His proposal to repudiate Aristotle altogether, and appeal to nature by experiment, was also very unpopular. He spent forty years of his life in study, and over £2,000 in buying books and materials and in traveling; and his own reward was neglect, poverty, and persecution. Fortunately for the world, Clement IV, who had been his friend before his elevation to the papal chair, encouraged him to write, and at his instance he produced these works which have placed him among the immortals: The Opus Majus, Opus Minus, Opus Tertium, and Compendium Philosophiæ. The first of these, planned on a splendid scale, is divided into six parts, as follows:

(1) On the four causes of human ignorance; authority, custom, popular opinion, and the pride of supposed knowledge. These seem to bear a kind of lurking resemblance to Lord Bacon's Idols of the Tribe, the Cave, the Market Place, and the Theatre; but, for whatever connection there is, Francis, and not Roger, must be held accountable.

(2) On the causes of perfect wisdom in the Sacred Scriptures.

(3) On the usefulness of grammar.

(4) On the usefulness of mathematics. This is again subdivided into—

> (*a*) The necessity of mathematics in human things.
>
> (*b*) The necessity of mathematics in divine things. These are enumerated as geography, chronology, cycles, and natural phenomena, arithmetic, and music.
>
> (*c*) The usefulness of mathematics in ecclesiastical things, e. g., the certification of faith, and the correction of the calendar.
>
> (*d*) The usefulness of mathematics in the State, for the sciences of hydrography, geography, and astrology.

(5) On perspective (i. e., optics), treated under four heads: The organs of vision, the propagation of light in straight lines, reflection and refraction, and the propagation of the impressions of light.

(6) Of experimental science.

Whewell says of this work that its plan was "to urge the necessity of a reform in the mode of philosophizing; to set forth the reasons why knowledge had not made a great progress; to bring back attention to

sources of knowledge which had been unwisely neglected; to discover other sources which were yet wholly unknown, and to animate men to the undertaking by a prospect of the vast advantages which it offered." The work is thus a method, rather than a treatise on science; but part 5, on perspective, describes the anatomy of the eye, and is his own work. He also discourses on vision, the laws of reflection and refraction, and the construction of mirrors and lenses. Part 6 is again devoted rather to the philosophy of the subject than a description of experiments; but it includes an investigation into the nature and causes of the rainbow.

The Opus Minus is a summary of the Majus; Tertium, a preamble and supplement to the other two. Bacon's fiery energy appears in the fact that all three must have been written within eighteen months, though no trace of haste or carelessness appears in them. There is evidence that he intended all these works merely as a preliminary to a still greater one, of which the Compendium Philosophiæ is a part.

To do justice to him, and to give extracts showing the intellectual level on which he stood, would far exceed the limits of a page or two. One can only regret that such a man should not have been able to command the leisure and encouragement which would have been his lot in a more enlightened age. That he was a believer in alchemy, there is no doubt, but for this he can not be blamed; nor for a belief in magic, though he is most emphatic in assigning it a subordinate place. The one quotation which follows, from the Appendix to the Compendium Philosophiæ, will show to what extent he forecasted the labors of engineers and mechanicians, while at the same time he is evidently not letting his imagination run riot, but keeps within reasonable bounds, as if he knew the range of human powers.

"That I may the better demonstrate the inferiority and indignity of magical power to that of Nature and Art, I shall a while discourse on such admirable operations (of Art and Nature) as have not the least magic in them. - - - And first of such engines as are purely artificial.

"I. It is possible to make engines to sail withal, so that either fresh or salt water vessels may be guided by the help of one man, and made to move with a greater swiftness than others which are full of rowers to drive them along.

"II. It is possible to make a chariot move with an inestimable swiftness, such as the scythed chariots were, wherein our forefathers fought, and this motion to be without the help of any living creature.

"III. It is possible to make engines for flying, a man sitting in the midst thereof, by turning only an instrument which moves artificial wings made to beat the air, much after the fashion of a bird's flight.

"IV. It is possible to invent an engine of little bulk, yet of great efficiency, either to the depressing or elevation of the very greatest weights.

"V. A man may easily make an instrument whereby one man may, in despite of all opposition, draw a thousand men to himself, or anything which is movable.

"VI. A man may make an engine whereby, without any corporal

danger, he may walk at the bottom of the sea or other water. Such engines as these were of old, and are made even in our days. All of them, excepting only that instrument of flying, which I never saw, nor know any who hath seen it, with an infinite number of other inventions, are possible, such as the making of bridges over rivers without pillars or supporters."

As my intention is by no means to trace the early history of science in general, but merely to record what was done by English writers between definite limits of time, I have of course to omit all reference to the work of Geber, Albertus Magnus, Raymond Lully, and others. It is only too evident that in these seven centuries science would have fared very badly had its development been left to Englishmen alone; but a noble recompense for this neglect has been made since by a long line of busy workers from the days of Boyle and Hooke down to our own time.

THE PLACE OF RESEARCH IN EDUCATION.[1]

By H. E. Armstrong.[2]

The address on "Art tuition," delivered here a fortnight ago by Professor Herkomer, which I trust many of you had the advantage of listening to, was full of wise counsel, which can not fail to be of value to those who study it; the more so as Professor Herkomer is not only himself an artist of wide and varied experience, highly gifted with originality, but also an experienced teacher, and is therefore better able to advise than are most other artists. For, after all, only the competent teacher is fully aware of the difficulties which beset the path of the student.

But no advice given by Professor Herkomer was equal in importance to his opening statement—which was subsequently confirmed by members of the governing body—that in this polytechnic a clean beginning has been made in art; that you have advisedly elected to be free from all external control and are possessed with the fixed intention of working out your own salvation. Professor Herkomer begged—prayed, I may say—that you should be kept clear of all contagion, and all who are your true friends must join in this prayer.

I desire to preach from the same parable as regards the teaching of science—to exercise the functions of a medical officer of health for science; but my task is a difficult one. Professor Herkomer spoke to

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[2]The editor has been good enough to regard the following article as of sufficient interest to warrant its insertion distinctly with the object of showing that it is desired to deal with subjects likely to attract public attention, so as to interest a wider circle of readers in Science Progress. I have gladly accepted his hospitality, as I believe it to be of the utmost importance to interest scientific workers as well as the public in questions such as I raise. Unless we are prepared to throw ourselves more into such work, there is little probability that the teaching of scientific method will gain that popular recognition which the subject imperatively demands, and which so many of us are persuaded must without delay be accorded to it, if we are to retain any proper measure of national prosperity. It was recently delivered as an address at the Chelsea Polytechnic, and hence it is somewhat egotistical and dogmatic in style; however, I have thought it undesirable to change the style, desiring to lay as much emphasis as possible on the important issues which are considered.

willing ears; his meaning was clear; he was dealing with a popular subject of which we all have some understanding. I can not but recognize that my subject is generally misunderstood, and its public importance greatly underrated in consequence. Some inscrutable influence has led those who have organized this institute to appreciate the needs of art, and having had the wisdom to take proper advice, they have put you in possession of the elements of a perfect system of art sanitation; but the needs of the sister subject, science, have yet to be grasped here and elsewhere. The sanitary condition of the dwellings which science has to put up with throughout our country is most faulty, ill arranged, out of date, and oftentimes abominable; and if this polytechnic, indeed, polytechnics and schools generally, desire to place the teaching of science under healthy conditions, heed must be given to the inspector's warnings.

I might almost take Professor Herkomer's address, write science for art, add a few passages here and there, and redeliver it as my own. Decorative art, that art which enables artists to decorate, you were told can not be taught on the large scale; it can not even be taught in schools—it must be taught in the workshop. Decorative science, science which decorates its possessor and enables him or her to be scientific, scientific knowledge which can be made use of in the service of the world, also can not be studied except in the workshop and in nature, to whom also the artist must resort. As Professor Herkomer said most truly: all technical education will fail if established on a scheme in which the master's personality is eliminated, and that must follow in any scheme of wholesale tuition.

But what meaning have the words "science" and "scientific" in English ears generally? Do they excite visions of a complicated picture of things concerning our daily life in its minutest details? Certainly not. Their utterance before those who know a little chemistry recalls fireworks and smells and perhaps simple salts; whilst those who take an interest in electricity have thoughts of bells ringing, galvanometer needles wagging, or glowing electric lights; and teachers dream of South Kensington certificates and hardly earned grants. In the minds of the general public they call forth no response, especially in those of that very numerous section of the community which is concerned in commercial transactions and has no knowledge of manufactures. Science in the eyes of the average Englishman consists of a newfangled set of ideas, all very well for those who can afford the time to study them, but in his opinion not of such daily practical importance that it is necessary for the nation to pay attention to them. And this unfortunately is the opinion even of "educated" men and of many men of culture. This is perhaps the primary defect in our system to which the medical officer of health for science is bound to call attention; it is one which we must all unite in overcoming and which polytechnics such as this should do much to remove.

If public appreciation of scientific procedure can be secured to even a moderate extent, a complete popular victory for those who press for its introduction must soon follow. The advantages to be derived from the general application of scientific method to the affairs of life are demonstrably so great that when once they are made known at all commonly its adoption will be insisted on.

Science is but exact knowledge, and there are as many branches of science as there are of exact knowledge. Remember, however, a loose incoherent body of facts does not constitute a science—a man who is merely possessed of such facts is not scientifically trained. A scientific man is a "knowing man"—not merely a man who knows, but one who is properly described in the terms of the popular expression—he's a knowing fellow—which implies something more than the mere possession of knowledge, namely, the power to use it properly and with effect. There is every difference, in fact, between the scientific and the merely learned man. To be scientific is to be as far as possible exact in thought, deed, and word; to act with a purpose and after due and careful consideration; to be observant and thoughtful; to be logical and methodical; to be guarded but fearless in opinions and judgment; and it is because we are so rarely all these that we are so rarely truly scientific.

Unfortunately, the word "science" is now associated in the popular mind with certain branches of natural knowledge, and it is because these are generally regarded as of importance only to those whose special business it is to attend to them that the proper application of the term is lost sight of.

I am not here to speak of science teaching—I do not know what that is—but of scientific teaching; of the method of teaching scientifically—that is to say, exactly and properly. I am really speaking on the very subject on which Professor Herkomer dilated; we are both pleading one cause although on behalf of somewhat different interests, and mine is the wider plea and will, in fact, include his. He was the advocate of a practical workshop method of art tuition, under a teacher free as well as competent to consider the peculiar qualities and requirements of his pupils; of a method of so training students as to develop to the utmost their individual innate talents, instead of turning out a set of mechanical automata, blind followers of fashion. I desire to urge that whatever we teach, our method shall be scientific, so that students, in proportion to their abilities, may learn to honestly and usefully apply whatever knowledge they may become possessed of.

Institutions such as this have a great field of usefulness before them if all their work be done from such a standpoint; if it be not they will be absolute and costly failures. I much fear that unless a change in policy, almost amounting to a revolution, take place in many of the schools throughout the country devoted to what we are now pleased to call technical education, the results will be disastrous.

Let us consider what has been and is being done. Until about

twenty years ago, besides our universities, the three London colleges and Owens College, Manchester, the country had little to boast of in the way of institutions for higher learning to which those who had left school could resort; but then important university colleges were founded in rapid succession in a number of the chief provincial towns. Meanwhile the educational fever spread to London, and there assumed an extremely acute form under the name of technical education. The City and Guilds of London Institute was founded, and built first the Finsbury Technical College, and later the Central Technical College at South Kensington, besides establishing an art school at Lambeth; and by taking over, fostering, and largely extending the system of technological examinations initiated by the Society of Arts, the City Guilds Institute exercised an extraordinary influence on the establishment and conduct of evening classes for instruction in technical subjects throughout the country. A further development of the same spirit has led more recently to the erection here, there, and everywhere throughout London of polytechnics, etc., and of a large number of technical schools of various degrees of importance in the provincial towns.

Why, it may be asked, all this educational activity, and why especially did the cause of technical education so suddenly spring into prominence? The answer is, you know, because the conviction arose that our manufacturing industries were being seriously threatened in consequence of our failure to sufficiently avail ourselves of scientific aid, and the greater appreciation by foreigners of the services of scientifically trained workers. Because a feeling was abroad such as was graphically expressed by Huxley in a remarkable letter to the Times at the close of 1886 in which he pointed out that we had "already entered upon the most serious struggle for existence to which this country has ever been committed," adding "the latter years of this century promise to see us embarked in an industrial war of far more serious import than the military wars of its opening years. On the east, the most systematically instructed and best-informed people in Europe are our competitors; on the west, an energetic offshoot of our own stock, grown bigger than its parent, enters upon the struggle, possessed of natural resources to which he can make no pretension, and with every prospect of soon possessing that cheap labor by which they may be effectually utilized. Many circumstances tend to justify the hope that we may hold our own if we are careful to organize victory."

The question is, Have the steps we have taken to protect ourselves, to hold our own, to organize victory, led to success? In most cases, most certainly not. We are fast proving ourselves to be incapable of holding our own in almost every branch of industry.

Of course there are certain brilliant exceptions to the general rule, but these only prove the rule and enable us to understand the cause of our failure.

Why is this? It is, I believe, because our character is so firmly set that nothing but severe compulsion will lead us to reform. It is because, whatever we may term ourselves politically, we are all by nature ultraconservative, the rankest political radicals amongst us being the strongest conservatives in their general conduct. It is due to our intense belief in ourselves, the outcome of a long period of unexampled prosperity. We are so intolerantly individual that we can not bring ourselves to organize and cooperate, and this probably is the main source from which our difficulties spring. Let me take an illustration from agriculture, the most important of our industries, but one which, as all know, is in a terribly depressed condition. We are told that last year £36,000,000 worth of butter, cheese, eggs, hams, bacon, fowls, ducks, etc., was imported into this country. Surely we ought to be capable of producing most of these.

As a matter of fact, we can not even make decent butter or cheese yet. As Sir Henry Gilbert, the distinguished agricultural chemist, remarked to me lately when we were sitting together at dinner, "In our village we prefer to buy Brittany butter rather than the local 'best fresh.'" If we could do such things it would not be necessary for the Yorkshire College, our leading university college, to send out peripatetic teachers to instruct dairymaids, or for county councils all over the country to do similar work, nor would the Duke of Devonshire have been called on, as he was a few weeks ago, to open a midland dairy institute. In France they have long known not only how to make butter properly, but what to do with it when they have made it, an important art which we, from our inability to organize, have also yet to learn. Let me recite my own experience in this matter.

My father was largely concerned with the Normandy butter trade, and on one occasion, about thirty years ago now, I visited France with him; nothing I have since seen has ever impressed me more. The morning after our arrival we were driven out to a market town in the district, where we found all the country folk collected together, each having brought whatever produce they could command to market; our friend, and I should say that the active worker was a woman, went rapidly round the market, tasting each parcel of butter and offering what was thought to be its value, which, of course, was not the retail price of best fresh. If the bid was accepted, note was taken by a clerk. On our return, after dinner, in the evening, we found that the butter had not only been collected and brought in, but we actually saw it being carefully mixed and salted and colored to standard, so as to make it all of one uniform quality, enough to fill a large number of casks being thus dealt with. The next morning it was on the rail and on its way to England. No such thing, I believe, has ever yet been done in this country.

As to eggs coming from abroad, a recent remark made by Sir J. B. Lawes occurs to me: "That it is not that we do not produce them, but we eat them nearly all ourselves." It may be well for us that we do,

but the fact is none the less an illustration of the absence from England of thrifty habits such as characterize other nations.

Again, to illustrate why we are beaten by others, let me refer to the fate that has befallen what was formerly an important English industry—the manufacture of colors from coal tar, which is now practically in the hands of the Germans and Swiss, so much so that Dr. Caro, the chief living authority on these matters, in addressing the German Chemical Society a couple of years ago, was able to refer to it as a German national industry.

It was established in 1856 at Sudbury, near Harrow, by Perkin, who discovered the first aniline color in the course of a research which he was carrying out, with purely scientific objects in view, under the direction of Hofmann, then professor in the Royal College of Chemistry, in Oxford street, London. Soon afterwards the important firm of Simpson, Maull & Nicholson was founded at Hackney Wick—Nicholson being another of Hofmann's pupils. Although similar works were erected in France and Germany, the main business remained in English hands during perhaps twenty years. Meanwhile Dr. Griess, chemist throughout his life to the celebrated brewers at Burton-on-Trent, Messrs. Allsopp, was carrying on researches on diazo compounds, which he had begun as a student in Germany—one of the most remarkable series of scientific researches ever made; but these did not meet with full appreciation until 1876. In this year the firm of Williams, Thomas & Dower, of Brentford, introduced certain azo colors into the market which had been made in their works under the direction of a most accomplished Swiss chemist, Dr. O. N. Witt, strictly in accordance with Griess's prescriptions. The importance of the step thus taken was not fully apparent here, but it was in Germany. Dr. Caro, a member of the now world-renowned Badische Anilin und Soda Fabrik, near Mannheim on the Rhine, who had formerly been chemist to Roberts, Dale & Co., in Manchester, the personal friend of Griess, had been working in the same direction as Witt, and his firm shortly afterwards brought out azo colors similar to those manufactured by the English firm. This time the seed had fallen upon fruitful soil; the Germans were theoretical as well as practical, and at once saw that the application of Griess's discoveries was likely to be productive of practical consequences. They largely increased their scientific staff, research became the business of the works, and the industry expanded at an extraordinary rate, while the English manufacturers, remaining unteachable, and having no proper scientific staff in their employ, were simply snuffed out.

And the story has yet another side. You have all heard of the turkey-red or madder dyes, formerly obtained from the madder plant, which was very largely grown in France, Holland, and Turkey. In 1868, two German chemists prepared alizarin, which is the chief constituent of madder, artificially from anthracene, a substance contained in coal tar.

Now, Perkin, when a student with Hofmann, had worked with anthracene, and seeing the practical importance of the discovery, again set to work and anticipated Graebe and Liebermann in the discovery of a process of manufacturing alizarin. He at once began to make it artificially. His works prospered, and during several years the production of artificial alizarin was an English industry. But Perkin made the unfortunate "English" mistake of working almost single-handed. The Germans, meanwhile, were silently but steadily working in their characteristic manner, studying every detail, and soon came to the fore and became masters of the situation.

Perkin's business is now continued as the British Alizarin Company. The conditions under which this firm is working are somewhat peculiar, and such as to procure for it considerable advantages, but the success which has attended its labors is sufficient to show that such an industry might be carried on with special advantage in this country if organized in the proper spirit. Several years ago I had the opportunity of visiting the works shortly after I had inspected the most fully equipped factory of the kind in Germany, and I was agreeably surprised to find that the English works were distinctly in advance of their continental competitors, being able to deal economically with larger quantities. But whereas here the anthracene-color industry is much as it was, abroad it has expanded in various important directions which are proving highly remunerative, whilst the original madder dyes, although produced in larger quantity than ever, are made at slight profit, owing to the excessive competition that has arisen.

Now artificially made dyes have all but displaced natural coloring matters, indigo excepted, even among so conservative a people as our Indian subjects, and the industry is of enormous importance, although not to us. We are so much behindhand in the race that there is little chance of our regaining a good place in the list of runners, even if we go fully into training with that object.

And not only dyestuffs are made from coal tar. A whole list of substances of the greatest value in medicine are also now prepared from raw materials derived from tar; some of these have proved to be most efficient substitutes for quinine, and the growth of cinchona bark in India and Ceylon has consequently ceased to be the remunerative pursuit it was. All such substances have been the outcome of researches carried out in the German universities, or in the still more highly equipped laboratories of the German chemical works. Moreover, of late years nature's perfumes have one after the other been forced to disclose their character to the pertinacious inquirer, and have been claimed as victims by the chemical manufacturer abroad, although here again the example was first set by Perkin, who in 1868 showed how coumarin, the odoriferous principle of the Tonka bean, might be artificially prepared.

If we seek to understand our early success as well as our later failure

in the branch of industry of which I have been speaking, it is not difficult to trace the former to Hofmann's influence and the latter to our want of appreciation of the inestimable value of the services of such a man. In this connection, I may be allowed to quote from my presidential address to the Chemical Society in 1894 the following passage in reference to the then recently published memoir by Dr. Caro on the development of the coal tar color industry:

"To those who can understand it, the story told by Caro is nothing less than an epic, but it is one the contemplation of which must in many ways sadden an Englishman, elevating though it be when regarded from the purely scientific point of view. Full and complete recognition of Hofmann's services to the industry characterizes every page of the monograph, and the only ground of complaint which some of us feel that we have against the writer is that his own great services are nowhere referred to. Wherever they received their early training, the true education which experience in the world alone gives was gained by both Hofmann and Caro while in the service of English masters; and it is an interesting problem for speculation whether, had they remained with us, our position would not have been a different one. Germany could scarcely have accomplished what it has done without them, but by years of patient labor her universities had laid a broad and solid foundation on which alone such men could build. Here, such men had neither brick nor mortar offered to them either by the universities or manufacturers, and such is our disregard of theory in this country of 'practical men,' that we even now have not learned the lesson which the contemplation of the success of German chemical industry teaches; shall we ever learn it properly? In London, at all events, we shall probably wrangle during years to come about the establishment of a university worthy of the greatest city in the world, which will set an example and help us again to do our fair share of the work which has been taken from us; and it will be years, apparently, before English manufacturers will all learn to spell the word "chemist"—and that it will acquire some meaning for them. But it is much to be feared that recantation may come too late, and that the opportunity will have been lost. America, perhaps, will meanwhile have learned the lesson also, and the competition we shall have to meet will not be European alone; we have not only to go ahead as fast as others, but to make up for much lost time, and it is not likely that others will calmly stand by while we make the attempt.

"Such is the lesson which we may derive, it seems to me, from the study of Hofmann's career and the attendant circumstances; and it is one which we in this society must take very deeply to heart."

At the present day, no matter what his business, the German manufacturer seeks to understand every detail, and he is always trying to improve his processes. He attains this end by availing himself very fully of the services of men trained scientifically at the university, men who have all served their apprenticeship in the school of research; in fact, no man who has not been so trained is looked at nowadays by the German manufacturer.

In proof of this, I may quote words used by Dr. O. N. Witt, now professor of chemical technology in the Berlin Royal Technical High School, the most important institution of its kind in the world, in his

report to the German Government as their commissioner at the Chicago Exhibition in 1893. Says Dr. Witt:

"What appears to me to be of far greater importance to German chemical industry than its predominant appearance at the Columbian World's Show is the fact which finds expression in the German exhibits alone, that industry and science stand on the footing of mutual deepest appreciation, one ever influencing the other. By affording proof that this is truly the case, Germany has given an indisputable guaranty of the vitality of its chemical industries."

Our policy is the precise reverse of that followed in Germany. Our manufacturers generally do not know what the word "research" means; they place their business under the control of practical men, often admirable men in their way, possessed of much native wit, but untrained and therefore too often and necessarily unprogressive; and such men as a rule actually resent the introduction into the works of scientifically trained assistants. Hence there is no demand here for men who have been carefully trained as investigators; consequently our schools do not seriously attempt to train investigators. In this country such people are only born and grow spontaneously, the high class manufactured article is made in Germany alone. We elect to sacrifice at the altars of the examination fiend, for god he can not be called, and do our best to discourage the development of originality.

Let me give an illustration to make my meaning clearer. Recently I met a friend who has not only distinguished himself by his intelligent criticism of a particular industry, but has become so interested in it that, having means at his disposal, he has himself become a manufacturer, affording a rare illustration of enterprise. I said: "I trust you are going to work on German lines and engage a good chemist to systematically study your material, and so ascertain how its properties vary with its composition; for I have reason to think from direct experience that much is to be learned in this way which will make it possible to put the manufacture on a scientific basis." His ready answer was: "Oh, I've got to make the business a commercial success!" Of course I understood what he meant while I felt that he could not fathom my meaning—he was too much an Englishman to do that. No doubt he will place his business in the sole charge of a practical man, and as long as it suffices to look only at the surface he will succeed; but then, not improbably, the Japanese will come in and beat him, for they have shown the world that they can organize as well as appreciate scientific method.

Or, to give another example showing what may be accomplished under English conditions by adopting foreign methods, let me refer to work done by Mr. Mond, so well known in this country on account of the skill he has shown in developing Solvay's ammonia-soda process. Mr. Mond has long been engaged in seeking for a solution of the problem—how to burn fuel electrically, in such a manner, that is to say, as to directly produce electricity instead of heat. Having improved the gas

battery devised in 1842 by the present Sir William Grove, in which hydrogen is burnt electrically, he was anxious to obtain a method of preparing hydrogen readily in large quantities. No good method is known, but a mixture of hydrogen and carbonic oxide is easily made, and even Mond found that on passing this mixture over heated nickel the carbonic oxide was converted partly into carbon and partly into carbondioxide, and as the latter was easily removable, he thus succeeded in a measure in effecting his object.

In studying the very remarkable action which nickel had on carbonic oxide, it so happened that on one occasion when experiments were being made in his laboratory the escaping gas was led into the flame of a burner so as to set fire to it, a necessary precaution, as the gas is highly poisonous; it was noticed that instead of burning as usual with a nonluminous smokeless flame it burnt with a slightly luminous flame. This strange circumstance led to inquiry being made, and it was eventually ascertained that the metal nickel, under certain conditions, combined with the gas carbonic oxide, forming a very volatile colorless liquid, and thus one of the most remarkable discoveries of modern times was made. The discovery was communicated to the Chemical Society in 1890 by Mr. Mond in conjunction with his assistants, Drs. Langer and Quincke. Having observed that the compound was very readily broken up into carbonic oxide and nickel, Mr. Mond at once set to work to devise a practical method of preparing nickel on a large scale from its ores through the agency of the new compound, and after spending not only much time and labor, and I believe also a very great deal of money, on his quest, was successful in devising a process which he has carried out on the large scale during several months past, and which has enabled him to produce over a ton of metallic nickel of almost absolute purity per week—perhaps the greatest achievement in metallurgy on record. Such action on the part of a native-born English manufacturer is "unthinkable," at least I know of no precedent which would justify us in regarding it as possible under present conditions. I only recently heard of a firm who are doing work of a most important and critical character, involving the expenditure of a very large amount of money, who, having asked an expert whether it would not be well to carefully observe the temperature at which their operations were conducted, on being advised that it was most important to do so, objected that an instrument for the purpose, costing £25, was too expensive to use. The foreign worker would seek to know what happens at any cost.

If the English nation is to do even its fair share of the work of the world in the future, its attitude must be entirely changed—it must realize that steam and electricity have brought about a complete revolution; that the application of scientific principles and methods is becoming so universal elsewhere that all here who wish to succeed must adopt them, and therefore understand them. It rests with our

schools to make the change possible. To repeat what I said in 1894 in the presidential address before referred to:

"There can be no question that the future of this country is very largely in the hands of its schoolmasters and schoolmistresses, and there are many among us who are convinced that our progress is much hindered by their failure to feel the pulse of the times—who think, indeed, that they do not suitably prepare the material which we subsequently are called on to mold into its final shape. We look to the new commission to recommend drastic changes which will enable us to utilize to the full the marvelous ability latent in the English race, and which will help parents in solving the truly terrible problem with which they are confronted in these days of unreasoning and unreasonable competition when the time comes to secure a career for their children. English boys and girls at the present day are the victims of excessive lesson learning, and are also falling a prey, in increasing numbers year by year, to the examination demon, which threatens to become by far the most ruthless monster the world has ever known either in fact or in fable. Ask any teacher who has to do with students fresh from school his opinion of them, he will say that in the great majority of cases they have little if any power of helping themselves, little desire to learn about things, little if any observing power, little desire to reason on what they see or are called on to witness; that they are destitute of the sense of accuracy and satisfied with any performance however slovenly; that, in short, they are neither inquisitive nor acquisitive, and as they too often are idle as well, the opportunities offered to them are blindly sacrificed. A considerable proportion undoubtedly are by nature mentally very feeble, but the larger number are by no means without ability, and are in fact victims of an acquired disease. We must find a remedy for this state of things or perish in the face of the terrific competition now setting in.

"Boys and girls at school must be taught from the very earliest moment to do and to appreciate. It is of no use our teaching them merely about things, however interesting—no facts must be taught without their use being taught simultaneously; and, as far as possible, they must be led to discover the facts for themselves. Instead of our placing condensed summaries in their hands, we must lead them to use works of reference and acquire the habit of finding out: they must always be at work applying their knowledge and solving problems. It is a libel on the human race to say, as many do, that children can not think and reason, and that they can only be taught facts; early childhood is the time at which these faculties are most apparent, and it is probably through failure to exercise them then that they suffer atrophy. The so-called science introduced into a few schools in answer to the persistent demands of its advocates has been in most cases a shallow fraud, of no value whatever educationally. Boys see oxygen made and things burnt in it, which gives them much pleasure; but, after all, this is but the old lesson learning in an interesting shape, and has no superior educational effect. I would here repeat what I have recently urged elsewhere, that in the future all subjects must be taught scientifically at schools, in order to inculcate those habits of mind which are termed scientific habits; the teaching of scientific method—not the mere shibboleths of some branch of natural science—must be insisted on. No doubt some branch of chemistry, with a due modicum of physics, etc., is the subject by means of which we may, in the first instance, best instill the scientific habits associated with experimental studies,

but it must be the true chemistry of the discoverer, not the cookery-book-receipt pseudoform which has so long usurped its place. Whatever be taught, let me repeat that mere repetition work and lesson learning must give place to a system of allowing children to do things themselves. Should we succeed in infusing the research spirit into our teaching generally, then there will be hope that, in the course of a generation or so, we shall cease to be the Philistines we are at the present time; the education given in our schools will be worthy of being named a 'liberal education,' which it never will be so long as we worship the Old World classical fetish, and allow our schools to be controlled by those who reverence this alone, having never been instructed in a wider faith."

And what are schools such as this to do? Should they not also teach in the same spirit? As the secondary education commissioners point out—education must ever become more practical—a means of forming men (and they should have added, and women) not simply to enjoy life, but to accomplish something in the life they enjoy.

To this end, every school, I believe, whether in this metropolis or elsewhere, must work out its own salvation; and we must not look for payment on results, or countenance examinations which reduce all to one dead level.

When Professor Ayrton and I were appointed the first professors of the City and Guilds of London Institute—he having cut his educational teeth in the service of the Japanese and I having been largely made in Germany—we found ourselves in complete agreement that we would have nothing to do with teaching for examinations. Those who afterwards became our colleagues in the establishment of the Finsbury Technical College, my friends Mr. (now Sir Philip) Magnus and Professor Perry fully shared this view, and we all saw that a big problem in education lay before us which we could only work out if we had complete liberty of action, and the committees we had to do with never for one moment questioned this—all honor to them. I am proud to say that the programmes of the guild's colleges have never been disfigured by references to examinations as objects to be kept in view by students, and I venture to think that when the time comes to consider without prejudice the services which the city guilds have rendered to the cause of education, it will be admitted that they, more than any other body, have shown true appreciation of English needs. It is worth while noting that although it has never been a coaching college, the Finsbury Technical College has always been overfull, which disposes of the assertion that the bait of an examination must necessarily be held out as an attraction.

But what have the polytechnics done? To what extent have they made a clean beginning in all subjects; and to what extent have they been suborned to worship at the examination shrine to earn the unholy money bribe called payment on results?

I am told that the latter course is adopted in some cases, not because it is felt to be the right one, but because it would not do for Polytechnic

B to appear behind Polytechnic A in regard to the number of certificates gained—governors might object! Unfortunately, we know that such arguments are held, that quantity counts for more than quality. The English manufacturer can appreciate a big order, but will not undertake to carry out a small one; and here the foreigner steps in, and having made a beginning, gradually improves his position until finally he is left in practical possession of the field. Perhaps if we attended more to quality in education there would soon be a large increase in its quantity. A large proportion of those who at present come forward to be prepared belong to Professor Herkomer's great class of those who ought not to be taught at all. Among these are the certificate hunters brought into existence by school boards and other authorities. There is more than sufficient work to be done among those who are deserving and capable.

To quote Professor Herkomer: "No system could act more perniciously on the morals than payment on results. A few schools have through their strong masters and in some cases strong local help shaken off all the trammels of danger. The fact is, it has all grown into an unwieldy piece of machinery with all the deadening effect of impersonality in teaching. The whole system, when it is not practically upset by a strong and independent master, is lifeless, humdrum, and, above all, soul-deadening. It is the despair of the masters and the disappointment of the brighter pupils." To all which I say, Amen!

The system was established at a time when the many schools to which I have referred were unknown, and it was largely because the desired result was not obtained under the system that these new schools became necessary and were founded. How futile, then, must be any attempt to base the instruction in these new institutions on discredited methods—such old wine can not be put into such new bottles. Time does not allow of my fully discussing this matter. I can only point out that the programmes of instruction on which the examinations are based are of such a nature as to make real instruction impossible—even if no other objection could be raised, the extent of ground to be gone over is so great as to make cram an absolute necessity. We have to bear in mind that Germany has prospered without such examinations; Japan also. I believe China is the only country in which a similar system meets with national support. Recent events do not encourage us, however, to derive any consolation from this circumstance.

As Professor Herkomer points out: "Granted that the Kensington system was of use once upon a time, and that without it schools of art would not have been established at all, we must look the matter straight in the face and acknowledge that we have now arrived at a point when it must change its form in order to fulfill a great duty and to be of use, or else be disbanded." Undoubtedly this is so, and is as equally true of science as of art. The department has at last perforce itself recognized the necessity of change, but all too slowly, and by appointing a

certain number of inspectors has in a measure initiated a new policy. The very distinguished scientific man who is the director of science, in his evidence before the Royal Commission on Secondary Education, openly stated indeed that if he had his way he would entirely substitute inspection for examination in the elementary stage; but it is to be feared, unfortunately for the country, that in this, as in most other cases, one swallow does not make a summer.

Professor Herkomer insists that in the future freedom of action must be given to each master—to each town. This independence, he says, is to be obtained only by municipal and county council aid. "Emancipation from the apron strings of Kensington through municipal and county council support would produce an individuality," we are told, "in the art of each town," for which I may substitute, in the way in which science was taught and applied in each town.

But we must be careful that in leaving the science and art frying pan we do not jump into a worse municipal fire, of which there is clearly some danger; for while all the world is engaged in decrying examinations, our county council is bent on devising new ones. Scholarships at times are of great value to students, provided they fall into the right hands, and are obtained as well as held under right conditions. But it is easy to give too many scholarships, and still more so to give them to the wrong persons. Unless the examinations are placed in very competent hands, not only will a serious injury be done to our general system of education by leading those who are preparing boys and girls to adopt methods which it is unwise to follow in schools and to unduly force on their pupils, but the wrong people may be selected; the growth of a class of overtrained pot hunters may be encouraged instead of a vigorous, keen-witted, observant, and resourceful race. Those who prove themselves the most apt scholars under the tutelage of the crammer, however able as desk workers, may in the end entirely disappoint the hopes of those who desire most to encourage the development of ability. Huxley has said much as to the importance to the nation of catching the potential Faraday, but it is doubtful whether such would ever shine in a competitive examination in which among other tasks they were asked to write an essay on Oliver Cromwell, or some other like topic equally remote from the daily experience of a healthy lad. If we depend too much on examinations we may easily select the unfittest for the work of the world, and unless very careful we are almost bound to select but one kind of ability—clerical rather than practical ability; unless, indeed, we altogether change our system of school education, and examine very differently.

It is also difficult to understand what is to be gained by examining candidates for £5 evening scholarships; it must prove to be a very expensive mode of distributing such doles, and it ought to be possible to find some other more practical way of selecting those whose studies would be materially promoted by such a grant.

Clearly, therefore, it is essential that we should not lose sight of the fact that an exceedingly complex educational system is now growing up under the influence of men who, for the most part, are in no sense experts, and have but little knowledge of the details of such work, although possessed with the desire in every way to do service to the community and to improve our national position. It therefore behooves all who can follow such work to keep most careful watch on the march of events; otherwise those who seek to benefit may in the end do irreparable injury; the present is a most critical period in our history, and such watchfulness is imperatively demanded of us.

I have ventured on this digression because so much depends on the foundation laid at school, as technical studies can only be satisfactorily engaged in by those who have been well trained from the beginning.

As Professor Herkomer says, the kind of individuality to be developed in each town—or in the case of our huge metropolis, in each district—will vary according to the necessities of the community. In future each polytechnic in London must seek to ascertain what special work it can do to greatest advantage, instead of all following one example, as is too much the case at present. In words almost exactly those of my artist colleague: "This is the only way in which schools will obtain a direct influence over the industries of the country; and the influence will be the right one when the master is carefully selected, because it will be the school around a man and not a man struggling to be master in the midst of a system of impersonal teaching, where every student is expected to be squeezed into a great educational mangling machine." "Choose your master carefully," he says, "but then let him be master, and he will soon, with freedom of action, vary his forms of tuition according to the idiosyncrasy of each student, or the necessities of his immediate locality. The one true prize to be worked for would be individual progress. All teaching must be on a personal basis."

Choose your master carefully—this is indeed good advice. But this implies, of course, that those who have to choose know how; that they have some standard before them. Have they? Results seem to show that they rarely have. In this matter, as in many others, I believe, the City and Guilds of London Institute has set a good example by selecting men known to be capable of doing research work, and a large amount of research work has been done in its colleges. I am not aware that, excepting in the case of the principal of this polytechnic, capacity to undertake research work has been regarded as a qualification; on the contrary, for I know that when it was urged at one of them that a particular candidate had exceptional qualifications of this kind, the answer was: "We want a man to teach, not to do research." But the work of true education is pure research; really good teachers are engaged in nothing else, being constantly occupied in studying their pupils' idiosyncrasies and in devising suitable methods of instruction. The "researcher" is the equivalent of the artist; the teacher who can

not engage in research is the equivalent of the inartistic copyist. No subject is at a standstill in these days—all progress involves research, although not always original research. The young child, even, is constantly engaged in research, and the habit is only gradually lost at school under our highly developed, modern, soul-killing system of perpetual lesson-learning, itself largely devised to satisfy a system of payment on results.

Let us hope, therefore, that every board of governors will soon learn to appreciate the national importance of research, and will require evidence from every candidate for a teacher's post of ability in this respect. When such is the case, the research spirit will prevail also amongst students generally.

A most desirable example has been set in this direction by what, I suppose, may fairly be termed the least pretentious of the London polytechnics—that in the Borough road—which, with the assistance of the Leather Sellers' Company, has just opened a branch tanning school at Harolds Institute, Bermondsey, and with unblushing effrontery, one may say, prints on the programme under "Tanning School" the words, "with special research laboratory," and not content with this, informs us on the next page that "the special research laboratory is fitted up and supported by the worshipful company of leather sellers"—all hail to the leather sellers, let us say. An industry which makes such a new start, very late though it be, and recognizes the fact that research can help it out of its difficulties, is phenomenal in this country, but on the high road to retain its position if not to improve it.

I was much struck at the opening of the school by a statement made by the chairman, Mr. Lafone, M. P., who told us of an American customer who was in the habit of buying large quantities of a particular kind of leather here, of then taking it to America and manufacturing it, returning the goods here for sale. This man had remarked to him, he said, "that he had seen all our works and did not care a fig for our competition, for we had not even begun to know how to make the best." The introduction of the research spirit is sorely needed to cure such an Old World state of affairs as this.

Of course, whenever I advocate research in this way, and urge that the research spirit must be infused into all our teaching as well as into our national life, I am told it can not be done—that children can not solve problems. But there is a saying that an ounce of practice is worth a pound of theory; it is only a half truth, and a saying which is often misapplied, but it consoles me somewhat on such occasions. I have done it during the past fifteen years, since the opening of the Finsbury Technical College. No one has the right to say that it can not be done until they have tried; all who really try will succeed; those who do not should not attempt to teach.

HUXLEY AND HIS WORK.[1]

By THEODORE GILL.

I.

The history of scientific progress has been marked by a few periods of intellectual fermentation when great bounds have been taken forward and a complete revolution ensued. Very few have been such, but in one the name of Huxley must be ever conspicuous. It was as a lieutenant of the organizer of that revolution that he appeared, but unquestionably without him it would have been long delayed, and it was through his brilliant powers of exposition that the peoples of the English-speaking lineage soon learned to understand, to ome extent, what evolution was and, learning, to accept it.

On the 4th of May, 1825, was born the infant Huxley, in due course christened Thomas Henry. "It was," Huxley himself has remarked, "a curious chance that my parents should have fixed for my usual denomination upon the name of that particular apostle with whom I have always felt most sympathy." In his physical and mental peculiarities, he was completely the "son of his mother," whose most distinguishing characteristic was "rapidity of thought;" that characteristic Huxley claimed to have been passed on to him "in full strength," and to have often "stood him in good stead," and to it he was undoubtedly indebted for success in the many intellectual duels he was destined to be engaged in. His "regular school training was of the briefest," and he has expressed a very poor opinion of it. His early inclination was to be a mechanical engineer, but he was put to a brother-in-law to study medicine. The only part of his professional course which really interested him was physiology, which he has defined as "the mechanical engineering of living machines." The only instruction from which he thought he ever obtained the proper effect of education was that received from Mr. Wharton Jones, who was the lecturer on physiology at the Charing Cross School of Medicine. At Mr. Jones's suggestion, in 1845, Huxley communicated to the Medical Gazette (p. 1340) his first

[1] A memorial address given on January 14, 1896, before the scientific societies of Washington. Reprinted, with additions, from Science, February 21, 1896. New series, Vol. III, No. 60.

paper "On a hitherto undescribed structure in the human hair sheath." Two years later he contributed to the British Association for the Advancement of Science the first paper generally attributed to him, "Examination of the corpuscles of the blood of Amphioxus." (Abstracts, p. 95.) In 1845 he passed the first M. B. examination at the London University. Soon afterwards he was admitted into the medical service of the navy and was, after some waiting, assigned to the *Rattlesnake*, and for four years (1846–1850) served on her during her exploration of the Australasian seas; he was, he supposed, among the last voyagers "to whom it could be possible to meet with people who knew nothing of firearms—as [they] did on the south coast of New Guinea."

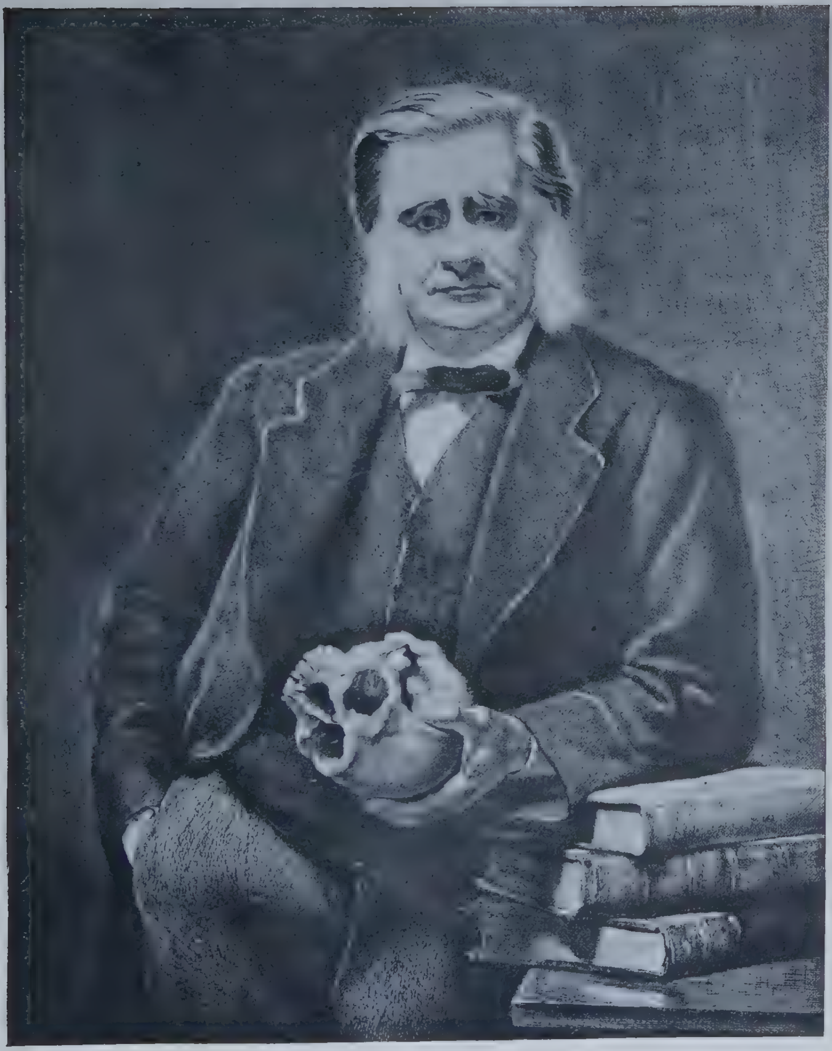
While on board Huxley zealously prosecuted zoological investigations, and in 1849 and 1850 sent records of various observations, in papers which were published in the Philosophical Transactions and Annals and Magazine of Natural History. Most important of all was a monograph on the Oceanic Hydrozoa, published by the Ray Society. It is amusing to find that while in Sydney he was impressed by MacLeay and lead to believe that "there is a great law hidden in the 'Circular system' if we could but get at it, perhaps in Quinarianism, too,"[1] but sober sense doubtless soon came to the rescue and he appears to have been never otherwise touched by the strange monomania that had been epidemic in England during the previous quarter century. In 1851 he became a F. R. S. He continued in the navy three years after his return, but in 1853 resigned when ordered to sea again.

In 1853 Huxley and Tyndall became candidates for professorships in the University of Toronto, but that university preferred others for the vacant places and thus missed the opportunity of an age. In 1854 Huxley was appointed to the post of lecturer on natural history in the School of Mines, which he held for the next thirty-one years. In the same year he became Fullerian professor in the Royal Institution. "The first important audience [he] ever addressed was at the Royal Institution." In 1862 he served as president of the biological section, and in 1870 of the British Association for the Advancement of Science itself; in 1869 and 1870 of the Geological and Ethnological Societies, and in 1883 to 1885 of the Royal Society. He was inspector of salmon fisheries from 1881 to 1885.

In 1876 he visited the United States and delivered an address at the opening of the Johns Hopkins University.

In 1885 failing health and desire for freedom led him to retire from most of his offices, and thenceforth he devoted himself chiefly to literary work rather than to scientific investigation. On the accession of Lord Salisbury to the premiership in 1892, Huxley was made privy counselor, and with it came the title of Right Honorable, by which he was later styled. In the last years of life he resided at Hodeslea, Eastbourne, and

[1] Ann. Mag. Nat. Hist. (2), VI, page 67.



THOMAS HENRY HUXLEY. (1825-1895.)
(From etching by Flameng after painting by Collier.)

after a long illness ("complication following influenza"[1]) died there on the 29th of June, 1895.

Such were the principal episodes in the life of Huxley. Many more details may be found in the numerous periodicals of the day, and in some of them are depicted various phases of his character and labors. The short time that is at our disposal to-night may be most profitably and entertainingly utilized in reviewing his feats as a warrior of science and estimating the measure of influence he exercised in diverting human thought from the ruts in which it had moved for centuries and directing it into a highway where increasing light from different sides could guide the wayfarer. Although this period of warfare was at its height not further back than the early afternoon of the present century, and some of us here assembled joined in the fray, to the younger naturalists it is an unknown past except through history, and to some of us who were of it, it is so strange as to recur to us rather as a dream than as a realized passage in actual life.

II.

Doubtless man, almost from the moment of his acquisition of those characters which distinguish him as representative of the genus Homo, had wondered and speculated as to how he came into being and how the animals assembled round him had sprung into existence. Those early concepts must have been strange, indeed, but were doubtless transmitted from mother to child, only with some eccentricities lopped off with advancing intelligence. Gradually, among peoples of the Aryan stock at least, they crystallized into a doctrine that in the beginning there was chaos, that the three elements of air, water, and earth were differentiated, and that animals were successively created to occupy the spaces. Such were the views of the old oriental cosmologists and such of the later Romans as epitomized in Ovid's verse. These ideas were long regnant and naturalists embodied some in their schemes, most accepting the idea that animals may have been created in pairs, but a few (such as Agassiz) urging that they must have been created in communities approximating to those still found. There were very few to dissent from these views of specific creation, and those few had little influence on the popular beliefs. But as the present century advanced, curious men delved into all the mysteries of nature; the sciences of morphology, physiology, histology, embryology, geology, and zoogeography came into being, and facts were marshaled from every side that militated against the old conceptions. Even when these sciences were inchoate, or new born, sagacious men had perceived the drift of the facts and anticipated induction by the formulation of hypotheses of evolution, but the hypotheses were too crude to insure acceptance. Meanwhile, however, the facts accumulated, and in 1859 a factor determining the

[1] Lancet, July 6, pp. 64, 65.

course of development of species was appreciated by Darwin and Wallace, and soon applied to a wide range of facts in the former's Origin of Species by means of Natural Selection.

Darwin's work at once aroused great popular interest, but it was too diffuse and the intellectual pabulum it contained was too strong and indigestible for ordinary readers, and it is probable that the general acceptance of the Darwinian form of evolution would have been delayed much longer than it was had it not been for the excursions from the scientific fold into the popular arena by one having the confidence of the former and the ear of the latter, as did Huxley.

Scarcely had Darwin's work come from the press when Huxley commenced his missionary work. Almost exceptional among numerous reviews, remarkable chiefly for crudity, ignorance, and arrogance, was one that appeared in the great daily organ of English opinion, The Times, marked by superior knowledge, acuteness of argumentation, and terse and vigorous style. This review, which attracted general attention, was acknowledged later by Huxley. Lectures and addresses before popular audiences, and even to those distinctively claiming to be "workingmen," followed, and these were published or supplemented by publication in various forms. Answers, critiques, and other articles in reply came out in rapid succession, and loud clamor was made that Huxley was an infidel and a very bad man, and that he falsified and misrepresented in a most villainous manner.

A memorable occasion was the meeting of the British Association for the Advancement of Science in the year 1860, following the publication of the Origin of Species. A discussion of the subject was precipitated by the presentation of a communication by our own Draper, "On the intellectual development of Europe with reference to the views of Mr. Darwin and others that the progression of organisms is determined by law." The reverend Mr Cresswell and the reverend Dr Wilberforce, Bishop of Oxford, followed in opposition, and they were answered by Huxley. The scene has lately been redescribed by a great physiologist and friend of Huxley, who is one of the few witnesses who now remain. "The room was crowded, though it was Saturday, and the meeting was excited. The bishop had spoken; cheered loudly from time to time during his speech, he sat down amid rapturous applause, ladies waving their handkerchiefs with great enthusiasm; and in almost dead silence, broken merely by greetings which, coming only from the few who knew, seemed as nothing, Huxley, then well-nigh unknown outside the narrow circle of scientific workers, began his reply. A cheer, chiefly from a knot of young men in the audience, hearty but seeming scant through the fewness of those who gave it, and almost angrily resented by some, welcomed the first point made. Then as, slowly and measuredly at first, more quickly and with more vigor later, stroke followed stroke, the circle of cheers grew wider and yet wider, until the speaker's last words were crowned with an applause falling not far short of, indeed

equaling that which had gone before, an applause hearty and genuine in its recognition that a strong man had arisen among the biologists of England."

The versatile bishop indulged in the argumentum ad hominem so very trite and familiar to us all (who has not heard it?) he would like "to hear from Mr. Huxley whether it was by his grandfather's or grandmother's side that he was related to an ape."

Huxley replied and answered: "I asserted, and I repeat, that a man would have no reason to be ashamed of having an ape for a grandfather. If there were an ancestor whom I should feel shame in recalling it would be a man; a man of restless and versatile intellect who, not content with an equivocal success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by an aimless rhetoric and distract the attention of his hearers from the real point at issue by eloquent digressions and skilled appeals to religious prejudice."

The arguments adduced against evolution during those days were sometimes very comical, and the confident air of the upholder of the ancient views and the assurance with which he claimed that his position was fixed and that the burden of proof rested entirely upon the advocate of the opposite view were very amusing. It was urged that no one had ever seen one species turn into another. Had anyone ever seen any animal made? Could anyone really conceive of any animal being actually made? Did an omnipotent Creator actually take the "dust of the ground" and mold it into animal shape and then breathe into its nostrils "the breath of life?" "Did infinitesimal atoms flash into living tissues?" Certainly no physiologist with a competent knowledge of histology could believe in any such mode of creation. On the other hand, everyone that could exercise the necessary skill could follow the evolution of an animal from an undifferentiated protoplasmic mass into a perfect animal. A clutch of eggs could be successively taken from a mother hen or a hatching oven, and day after day the actual evolution of the undifferentiated matter into derivative functional parts could be followed. That which is true of the hen is true of man, only in the latter case it is more difficult to obtain the requisite material and greater skill to use it is requisite. Compare the embryos developing in the hen and human eggs and at first no difference except size and environment can be perceived. Compare them in successive stages, and adult animals more or less parallel to some early stages may be found still living or entombed in earlier formations of the earth in fossilized form.

It was argued that no one had ever seen one species turn into another. But is it not a matter of historical evidence that many breeds of domestic animals have actually been developed by the agency of man and propagate their kind? And how are such breeds distinguished from species except by the fact that we know their origin, and

that they have come into prominence through selection by man rather than by nature? Interbreeding is no criterion.

But it is unnecessary to go into details, and these hints are offered only because their bearings on the subject were so generally overlooked by those who opposed evolution. One opponent, so eminent as to be styled the "pope" of a great Protestant Church, published a work against evolution largely based on the contention that the existence of the eye, except through direct creation, was inconceivable. Yet this very evolution of the eye from simple protoplasm could have been witnessed at any time with little trouble in the hen's egg. Is evolution through great reaches of time more inconceivable than actual evolution capable of daily observation?

Well and skillfully did Huxley meet the arguments against evolution. Even most of the old naturalists sooner or later recognized the force of the arguments for and the weakness of those against evolution. Those who did not in time gave up the contest with their lives. The young who later entered into the field of investigation have done so as evolutionists.

It is interesting to recall that the illustrious American (Professor Dana) who recently departed so full of years and honors, and of whom you have heard from a former speaker (Major Powell) to-night at length, in the full maturity of his intellect, accepted unconditionally the doctrine of evolution and dexterously applied it in his last great work.

III.

Darwin, in his Origin of Species, had refrained from direct allusion to man in connection with evolution and many casual readers were doubtless left in uncertainty as to his ideas on the subject. Naturally, the scientific man recognized that the origin of his kind from a primate stock followed, and believed that Darwin's reticence was probably due to a desire to disturb popular beliefs as little as possible. When we recall what strange views were held respecting man's origin and relations we can understand how the unlearned could easily fail to recognize that man must follow in the chain of his fellow-creatures. (We preserve creature still as a reminiscence of ancient belief, but without the primitive conception attached to the word.)

Man was claimed as a being isolated from animals generally, and naturalists of acknowledged reputation and one or two of great fame more or less completely differentiated him from the rest of the animal kingdom and even from the animal kingdom itself.

As long as the isolation of man from the animal kingdom, or from the greater part, was based on metaphysical or psychological ideas, the naturalist perhaps had no cause of quarrel, although he might wonder why a morphologist should stray so far from the field of observation. But when naturalists confused morphological and psycholog-

ical data, he had reason to protest. This confusion was effected by one of great eminence. There was no naturalist in Britain about the middle of the century who enjoyed a reputation equal to that of Richard Owen. An anatomist of preeminent skill and extraordinary industry, his merits had been appreciated by the entire world. An opinion of his had a weight accorded to no others. Consequently a new classification of the mammals, published by him in 1857, soon became popular. This classification was founded on alleged characters of the brain and on successive phases of increase in the cerebrum. Man was isolated not only as the representative of a family, but of an order and a subclass.

According to Owen, "in man the brain presents an ascensive step in development, higher and more strongly marked than that by which the preceding subclass was distinguished from the one below it. Not only do the cerebral hemispheres overlap the olfactory lobes and cerebellum, but they extend in advance of the one and farther back than the other. Their posterior development is so marked that anatomists have assigned to that part the character of a third lobe. It is peculiar to the genus Homo, and equally peculiar is the 'posterior horn of the lateral ventricle,' and the 'hippocampus minor,' which characterize the hind lobe of each hemisphere. The superficial gray matter of the cerebrum, through the number and depth of the convolutions, attains its maximum of extent in man. Peculiar mental powers are associated with this highest form of brain, and their consequences wonderfully illustrate the value of the cerebral character."

The views thus expressed by Owen were reiterated on various occasions, but many anatomists dissented from them, and the rumbling of a future storm was betokened. At last the storm cloud broke, and Owen was overwhelmed. At a great popular assemblage at Oxford, on the occasion of the meeting of the British Association for the Advancement of Science, Owen once more urged his contention of the cerebral characteristics of man, and maintained this wide difference from the apes.

Huxley immediately rose and, with that cogency of reasoning which characterized him, proceeded to divest the subject of the sophistries in which it had been enveloped. "The question," he said, "appeared to him in no way to represent the real nature of the problem under discussion. He would therefore put that problem in another way. The question was partly one of facts and partly one of reasoning. The question of facts was, What are the structural differences between man and the highest apes?—the question of reasoning, What is the systematic value of those differences? Several years ago Professor Owen had made three distinct assertions respecting the differences which obtained between the brain of man and that of the highest apes. He asserted that three structures were 'peculiar to and characteristic' of man's brain, these being the 'posterior lobe,' the 'posterior cornu,' and the 'hippocampus minor.' In a controversy which

had lasted for some years Professor Owen had not qualified these assertions, but had repeatedly reiterated them. He (Professor Huxley), on the other hand, had controverted these statements; and affirmed, on the contrary, that the three structures mentioned not only exist, but are often better developed than in man, in all the higher apes. He (Professor Huxley) now appealed to the anatomists present in the section whether the universal voice of Continental and British anatomists had not entirely borne out his statements and refuted those of Professor Owen. Professor Huxley discussed the relations of the foot of man with those of the apes, and showed that the same argument could be based upon them as on the brain; that argument being that the structural differences between man and the highest ape are of the same order, and only slightly different in degree from those which separate the apes one from another. In conclusion, he expressed his opinion of the futility of discussions like the present. In his opinion the differences between man and the lower animals are not to be expressed by his toes or his brain, but are moral and intellectual."

The appeal to anatomists was answered on the spot. The foremost anatomists of England there present (Rolleston and Flower) successively rose and indorsed the affirmations of Huxley. Not one supported Owen, and, brilliant as his attainments were, his want of candor entailed on him the loss of his eminent place, and Huxley took the vacated throne. But the contest that resulted in Owen's overthrow was of great service, for in the chief centers of civilization anatomists eagerly investigated the question at issue, and the consequence was that in a few years more material had been collected and studied than under ordinary conditions would have been done in five times the period. Unlike other battles, one in scientific warfare is almost always advantageous to the general cause, whatever it may be to a party.

IV.

The first important memoir by Huxley was written in his twenty-third year On the Anatomy and the Affinities of the Family of the Medusæ (Phil. Trans., 1849, pp. 413–434, pl. 37–39), and contained the germ of a fundamental generalization. He therein laid "particular stress upon the composition of [the stomach] and other organs of the medusæ out of two distinct membranes, as," he says, "I believe that is one of the essential peculiarities of their structure, and that a knowledge of the fact is of great importance in investigating their homologies. I will," he continues, "call these two membranes as such, and independently of any modification into particular organs, 'foundation membranes'" (p. 414). In his summary (p. 425) he also formulates "that a medusa consists essentially of two membranes, inclosing a variously shaped cavity, inasmuch as its various organs are so composed."

I have thus given Huxley's own words, inasmuch as Professor

Haeckel has asserted that Huxley therein "directed attention to the very important point that the body of these animals is constructed of two cell layers—of the ectoderm and endoderm—and that these, physiologically and morphologically, may be compared to the two germinal layers of the higher animals" (Nature, 1874), and Professor Kowalevsky has also claimed that Huxley "founded modern embryology by demonstrating the homology of the germinal layers of vertebrates with the ectoderm and endoderm of cœlenterates." (Nature, October 31, 1895, p. 651.)

In all candor, I must confess that, important as the generalization of Huxley for the Medusæ was, it was only applied by him to the Medusæ, and was not necessarily extensible with the homologies indicated, but it was pregnant with suggestiveness, and to that extent may have led to the wider generalization that followed. Let all possible credit then be assigned to it.

The classification of animals generally adopted, and in this country especially, up to at least the early years of the present half century, was based on what was called plan or type, and was mainly due to Cuvier. According to this school, there were four "great fundamental divisions of the animal kingdom," and these were "founded upon distinct plans of structure, cast, as it were, into distinct molds or forms." The term generally used to designate this category was branch or subkingdom, and the subkingdoms themselves were named vertebrates, mollusks, articulates, and radiates. Various modifications of this system and more subkingdoms were recognized by many zoologists, but the one specially mentioned was in very general use in the United States because favored by Agassiz, who then enjoyed a great reputation. Almost all naturalists of other countries, and many of this, recognized the distinctness, as subkingdoms or branches, of the Protozoans and cœlenterates. But Huxley, in 1876, went still further and segregated all animals primarily under two great divisions based on their intimate structure, accepting for one the old name, Protozoa, and for the other Haeckel's name, Metazoa.

"Among those animals which are lowest in the scale of organization there is a large assemblage which either present no differentiation of the protoplasm of the body into structural elements, or, if they possess one or more nuclei, or even exhibit distinct cells, these cells do not become metamorphosed into tissues—are not histogenetic. In all other animals the first stage of development is the differentiation of the vitellus into division masses, or blastomeres, which become converted into cells, and are eventually metamorphosed into the elements of the tissues. For the former the name Protozoa may be retained; the latter are coextensive with the Metazoa of Haeckel."

While not exactly original with Huxley, the recognition of these two great categories of the animal kingdom was hastened among naturalists, and found place in most of the works by men of authority that

followed. That such recognition greatly facilitates morphological concepts is certain. But most of the further new features of this classification have not received the approbation of naturalists generally.

V.—The Vertebrate Theory of the Skull.

Germany's great poet, Goethe, was "passionately devoted to the natural sciences," but was "induced by the habit of his mind to search for the general truths which give life to the dry bones of detail." In the Jewish cemetery of Venice, a broken sheep's skull came under his notice and he thought he recognized that it was made of modified vertebræ. Another German, Oken, in the Hartz mountains, "stumbled upon the blanched skull of a deer," and he was inspired with the idea that "it is a vertebral column." Oken immediately proclaimed his idea to the world. It found acceptance in many places and England's great anatomist, Richard Owen, took it up and carefully elaborated a new form of it. Owen's modifications, dubbed the "archetype" of the skeleton, became popular in Britain and America, and elements of the skull were described in terms indicating that they were "homotypes" with appendages of vertebra, the nasals, for example, being styled the neural spines of the nasal vertebra, the premaxillary the hæmal spine of the same vertebra, and the dentary of the lower jaw the hæmal spine of the frontal vertebra. But still more fanciful was the terminology for the limbs, the anterior being allocated to the occipital vertebra, and the scapula regarded as a pleuropophysis, the coracoid as a hæmapophysis, and the limb itself as a "diverging appendage."

Strange as this conception may appear to the young who have only been educated in modern methods, it had attractions for some, as I can testify from personal experience. When a boy I made an enlarged copy of the diagram republished in Carpenter's Physiology and colored the neurapophyses blue and the hæmapophyses red. Later reflection led me to the conclusion that an "archetype" should be more or less realized, and if it were not, it had no place in nature. As the Owenian archetype was at most only distantly approximated by specialized fishes, it could not be a true archetype of the vertebrate skeleton as such, however near it might represent the typical fish skeleton. Doubtless others were led by similar reasoning to discard the Owenian ideas, yet they continued in favor among many.

But in 1858, in a lecture on the Croonian foundation before the Royal Society, with Owen himself in the chair, Huxley discoursed "on the theory of the vertebral skull," and conclusively showed the inconsistency of the archetypal conception with the facts of embryology and development. After a recapitulation he confessed that he did "not perceive how it is possible, fairly and consistently, to reconcile these facts with any existing theory of the vertebrate composition of the skull, except by drawing ad libitum upon the Deus ex machinâ of the speculator—imaginary confluences, 'connations,' 'irrelative repetitions,' and shiftings of position—by whose skillful application it would not be

difficult to devise half a dozen very pretty vertebral theories, all equally true, in the course of a summer's day." He naturally reached not only "the negative conclusion that the doctrine of the vertebral composition of the skull is not proven," but "the positive belief that the relation of the skull to the spinal column is quite different from that of one part of the vertebral column to another."

The blow thus dealt against the Owenian archetype was a serious one, and it was nearly coincident with the growing adoption of the doctrine of evolution and the overthrow of the doctrine of types and patterns. At any rate, the old idea of the vertebration of the skull became an idea of the past. Owen continued to preach it, but his disciples abandoned it, and he was soon left without a single notable follower.

VI.—Classification of Ganoid Fishes.

The designation of Ganoidei was originally given by Agassiz to a heterogeneous group of fishes distinguished by a covering of what were called ganoid scales and having no other common characters; some of its representatives even lacked the "ganoid" scales. But most of the extinct species, at least, were really structurally affiliated and such were segregated by Johannes Müller in a comparatively natural group distinguished by cerebral, cardiac, and intestinal peculiarities, and for this group was retained the Agassizian term Ganoidei. Its constituents were contrasted under two subordinate groups named Chondrostei and Holostei. The families of the latter group were evidently related in various degrees, but such degrees were not expressed in the arrangement of the families, and the families themselves were mostly defined by superficial characters of little value. The appointment of Huxley to the professorship of natural history in the Government School of Mines led him to investigations which culminated in a "Preliminary Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch" (1861), and "Illustrations of the structure of the Crosstopterygian Ganoids" (1866). He proceeded "to reconsider the whole question of the classification of the fishes of this epoch, and, eventually, to arrive at results which seem to necessitate an important modification of the received arrangement of the great order of Ganoidei." He recombined the Chondrostei and Holostei, and then distributed the aggregate (which he designated as an order) into five suborders in the following manner:

Ordo GANOIDEI.[1]

Subordo I.—Amiadæ.

Subordo II.—Lepidosteidæ.

Subordo III.—Crossopterygidæ.

Fam. 1.—Polypterini.

Dorsal fin very long, multifid; scales rhomboidal.

Polypterus.

[1] Memoirs of the Geological Survey of the United Kingdom. Figures and descriptions illustrative of British Organic Remains, Decade X, pages 23, 24.

Subordo III.—CROSSOPTERYGIDÆ—Continued.

Fam. 2.—SAURODIPTERINI.

Dorsal fins two; scales rhomboidal, smooth; fins subacutely lobate.

Diplopterus, Osteolepis, Megalichthys.

Fam. 3.—GLYPTODIPTERINI.

Dorsal fins two; scales rhomboidal or cycloidal, sculptured; pectoral fins acutely lobate; dentition dendrodont.

Sub-fam. A. with rhomboidal scales.

Glyptolæmus, Glyptopomus, Gyroptychius.

Sub-fam. B. with cycloidal scales.

Holoptychius, Glyptolepis, Platygnathus [*Rhizodus, Dendrodus, Cricodus, Lamnodus*].

Fam. 4.—CTENODODIPTERINI.

Dorsal fins two; scales cycloidal: pectorals and ventrals acutely lobate; dentition ctenodont.

Dipterus [*Ceratodus? Tristichopterus?*].

Fam. 5.—PHANEROPLEURINI.

Dorsal fin single, very long, not subdivided, supported by many interspinous bones; scales thin, cycloidal; teeth conical; ventral fins very long, acutely lobate.

Phaneropleuron.

Fam. 6.—CŒLACANTHINI.

Dorsal fins two, each supported by a single interspinous bone; scales cycloidal; paired fins obtusely lobate; air bladder ossified.

Cœlacanthus, Undina, Macropoma.

Subordo IV.—CHONDROSTEIDÆ.

Subordo V.—ACANTHODIDÆ.

The chief merit in this arrangement is the appreciation of the closeness of the relations between the extinct fishes of the groups now recognized as Dipnoans and Crossopterygians, and the anticipation, by a kind of intuition, of part of the truth as now recognized. The "suborder Crossopterygidæ" of Huxley is really a compound of the subclasses or superorders of Dipnoans and Crossopterygians. The distinctive characters of the two were not recognized, and the author even failed to appreciate the exact relations of the living and extinct Dipnoans, or that, in fact, many of his Crossopterygidæ are really Dipnoans.[1] In his Anatomy of the Vertebrates (1871), even he retained his arrangement of the "Ganoidei," which were placed as the fourth order of fishes, and considered the "Dipnoi" after the Teleostei and as the sixth order of fishes. He failed even to find any extinct Dipnoans, and concluded his observations on the group with the statement that "It is a remarkable circumstance that, while the *Dipnoi* present, in so many respects, a transition between the piscine and the amphibian types of structure, the spinal column and the limbs should be not only piscine, but more nearly related to those of the most ancient Crossopterygian Ganoids than to those of any other fishes."[2]

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[1]The Polypterini, Saurodipterini, Glyptodipterini, and Cœlacanthini are alone regarded as "Crossopterygii" by recent palichthyologists, the Ctenodipterini and Phaneropleurini being regarded as "Dipnoi."

[2]It may not be out of place for me to remark here that even earlier, in 1861, than the publication of Huxley's paper, I had recognized the common characters of the

Finally, in 1876, Huxley published, as "No. 1" of "Contributions to Morphology," a memoir "On *Ceratodus forsteri*, with observations on the classification of fishes." He still persisted in separating the recent Dipnoans from the extinct forms combined with the Crossopterygidæ, and contended that "even *Dipterus*, which approaches *Ceratodus* and *Lepidosiren* so closely in its dentition and in the form of its fins, is far more similar to *Polypterus* and *Amia* in other respects; and there is at present no reason to believe that any of the Crossopterygian Ganoids possessed other than a hyostylic skull, or differed from *Polypterus* in those respects in which *Polypterus* differs from the existing Dipnoi. All known Crossopterygians have jugular plates, of which there is no trace in the Dipnoi."

It will be thus seen that the suborder of Crossopterygidæ was really the result of a misunderstanding and included most Dipnoans (and to such extent was a synonym for that group) as well as the Crossopterygians of later authors. It was by no means the exact equivalent of Crossopterygians, and consequently the latter name can not be considered as a synonym of Crossopterygidæ or be replaced by it. Nevertheless the introduction of the so-called suborder was not only the expression of an advance in our knowledge of the system itself, but paved the way for future investigators.

I am even inclined to credit mainly to his sagacity the early appreciation of the affinity of the *Neoceratodus* of Australia to the mesozoic Ceratodontids with all the far-reaching consequences that appreciation involved. It was in 1870 that the living Ceratodontid was introduced to the scientific world as *Ceratodus forsteri*, and thus generically associated with the mesozoic fishes. How did Krefft (or Clarke) get the idea of this association of a living fish with some known only from fossil teeth referred by Agassiz to the same family, as the Cestraciont sharks? In 1861 Huxley published his Preliminary Essay upon the Systematic Arrangement of the Fishes of the Devonian Epoch, and therein suggested that *Ceratodus* was a Ctenodipterine fish and ranged it (with a mark of interrogation) by the side of *Dipterus*. He also drew "attention to the many and singular relations which obtain between that wonderful and apparently isolated fish, *Lepidosiren*," and the Ctenodipterine

Dipnoi and Polypteroids, and for that reason combined the two in the subclass Ganoidei. In a discussion of the subject (Cat. Fishes N. Am., p. 15), I remarked that "Milne-Edwards again urges as a previously neglected argument in favor of the amphibian nature of *Lepidosiren*, the opening of the ductus pneumaticus of the pulmonary sacs into the ventral face of the digestive canal. But we also find a similar arrangement in the species of the genus *Polypterus*, animals whose piscine character and affinities have never been called in question:" also, "It is a fact of no little interest that the *Polypteri*, which have an air bladder so similar to that of the *Lepidosirenes*, do also, of all known fishes, most resemble them in the form and development of the different elements of the brain." They differ, however, in cardiac and osteologic characters. I concluded that "as the Dipnoi agree in all other essential respects with the Ganoids, we will then at least provisionally consider them as belonging to the same great subclass."

fishes. (The exact truth was not discovered, but was approximated.) Is it not probable that this memoir was known to Clarke, who claimed to have suggested to Krefft the systematic relations of the newly discovered Australian Dipnoan? It was creditable to both Clarke and Krefft that they did recognize this relationship and profited by their bibliographical knowledge, but it is doubtful whether they would have been able to make the identification or appreciate the importance of the discovery had not Huxley partly prepared the way. By this discovery, our acquaintance with the ichthyic faunas of both the present and past was almost revolutionized.

VII.

To the casual observer none of the terrestrial backboned animals appear to be less related than birds and reptiles. As Huxley remarks, "to superficial observation no two groups of beings can appear to be more entirely dissimilar. - - - Placed side by side, a humming bird and a tortoise, an ostrich and a crocodile offer the strongest contrast, and a stork seems to have little but animality in common with the snake it swallows." A difference in habits appears to be associated with the difference in form. The activity and freedom of the bird contrasts with the lethargy and restriction in range of the tortoise—the warm body of the former with the cold mass of the latter. The birds are looked upon as inhabitants of the air, the reptiles as degraded to crawling on the earth. The popular conclusions were to a considerable extent adopted by the scientific, and for a long time the birds and mammals were associated together as "warm-blooded" in contradistinction to the reptiles and other vertebrates, which were designated as "cold-blooded." This classification was in vogue in England when Huxley reopened the question as to the relative affinities of the vertebrates, and in 1864 claimed that the classes of that division "are capable of being grouped into three provinces—(1) the Ichthyoids, comprising Fishes and Amphibia; - - - (2) the Sauroids, - - - comprising Reptiles and Birds; and (3) the Mammals.[1] - - - The Sauroids (afterwards called "Sauropsida") agree in having "a single occipital condyle, a complex mandibular ramus articulated to the skull by a quadrate bone, nucleated blood corpuscles," and thus differ from the mammals, which have "a well-developed basi-occipital - - -; a simple mandibular ramus articulated with the squamosal and not with the quadratum, with mammary glands and with red non-nucleated blood corpuscles."

In 1868 Huxley directed his inquiries "on the animals which are most nearly intermediate between birds and reptiles." [2]

The differences between the recent members of the two classes are

[1] Lectures on the Elements of Comparative Anatomy, 1864, page 74.

[2] Annals and Mag. Nat. Hist. (4.), Vol. II, pages 66–75.

indeed many. The question, then, was How far can this gap be filled up by a reference to the records of the life of past ages?

"The question resolves itself into two:

"(1) Are any fossil birds more reptilian than any of those now living?

"(2) Are any fossil reptiles more bird-like than living reptiles?

Both of these questions Huxley found "must be answered in the affirmative."

The remains of Archæopteryx found in the "lithographic slate of Solenhofen" furnished a bird with decided reptilian characters—so prominent, indeed, that some of the paleontologists of the period claimed that the animal was a reptile rather than a bird.

The remains of various Dinosaurians of Mesozoic times yielded reptiles with characteristics manifest only among the birds of the present epoch. Such characteristics were especially exemplified in details of structure of the hind limbs. One of the Dinosaurians—*Compsognathus*—was so much like a bird in the legs that "it is impossible to doubt that it hopped or walked, in an erect or semierect position, after the manner of a bird, to which its long neck, slight head, and small anterior limbs must have given it an extraordinary resemblance."

From the vantage ground of the present, with its increased stores, we may justify Huxley's "hope" that he had redeemed his "promise to show that in past times birds more like reptiles than any now living and reptiles more like birds than any now living did really exist." There is now even a tendency to regard the differences remaining between the birds and reptiles as of less than class value, and to combine both groups in one and the same class—Sauropsida. The first to propose such a union was Professor Cope, who had even to some extent anticipated Huxley in the recognition of the similarity between the Dinosaurians and birds. The fact that two such men independently arrived at similar conclusions is significant as evidence for their truth. But there is danger of pushing a truth to the extreme of itself deceiving. There is still a great gap between any known reptile and any known bird. Huxley concluded with the caution that, "as we possess hardly any knowledge of the terrestrial reptiles of [the Triassic] period, it may be regarded as certain that we have no knowledge of the animals which linked reptiles and birds together historically and genetically, and that the *Dinosauria*, with *Compsognathus*, *Archæopteryx*, and the struthious birds, only help us to form a reasonable conception of what these intermediate forms may have been." This cautious statement is as apt for the present time as that in which it was expressed."

VIII.

One of the most persistent prejudices that has influenced the progress of zoological taxonomy has been (perhaps still is) a belief in the importance of superficial adaptation of structure for life in the water contradistinguished from life on the land. This prejudice was long impressed

on ornithology. The birds with feet adapted for swimming by the development of webs between the toes or for wading by elongation of the legs were set apart from those fitted mainly for progress on land or through the air: in other words, from those having negative characters in such respects. The major subdivisions of those groups, too, were almost solely distinguished by superficial characters of little importance, such as the form of the bill, the character of the claws, and the combinations of toes. Variations in such trivial characters, which in other classes of vertebrates would be esteemed of little systematic value, were assigned ordinal rank. Comparative anatomy, too, was almost entirely neglected in the classification of birds; even most anatomists were content to limit their observations to simple irrelative details or to interject them into the framework of existing arrangements. Such was the state of ornithology in 1867 when Huxley published, in the Proceedings of the Zoological Society of London, a memoir "On the classification of birds, and on the taxonomic value of the modifications of certain of the cranial bones observable in that class." In this he discarded the characters generally used and allowed himself to be influenced by the modifications to be found in the skeleton without reference to the habits or habitats of the birds. He reduced the orders to three—the Saururæ (extinct), the Ratitæ, and the Carinatæ. The last, including almost all the living forms, were divided into primary groups defined by modifications of "the bones which enter into the formation of the palate." "Four different modes" were recognized and were "called, respectively, the *Dromæognathous*, *Schizognathous*, *Desmognathous*, and *Ægithognathous* arrangement" (p. 425). It was urged that "these cranial characters may safely be taken as indications of natural affinities" (p. 454), and Huxley proposed "to regard these divisions as suborders, and to name them *Dromæognathæ*, *Schizognathæ*, *Desmognathæ*, and *Ægithognathæ* (p. 456). The last three suborders were divided into groups with the termination -morphæ, as Ætomorphæ (Raptores), Psittacomorphæ (Psittaci), etc., not taxonomically designated, but essentially equivalent to "superfamilies." The Ægithognathous "Coracomorphæ" corresponded with the "Passeres" as limited by recent naturalists, and Huxley was "disposed" to divide it "into two primary groups, one containing *Menura*, and the other all the other genera." How the immense aggregate represented by all the other genera were to be subdivided Huxley did not venture to decide, but he leaves the impression that he had little respect for the numerous "families" which had been recognized by most ornithologists.

The value of this work consisted chiefly in disturbing the old classifications and calling attention to the proper method of investigation. Much of it, nevertheless, appears to have been of permanent value, and most of the superfamilies at least have been recognized as natural assemblages, although still generally given ordinal or subordinal rank

and endowed with older names. The memoir at least gave an impulse in the right direction—morphological as opposed to teleological—and has incited to many elaborate investigations to the great advantage of ornithology.

IX.

Much doubt had existed respecting the nature of the non-mammalian ancestors of the mammals. It was supposed by some that they must have been reptiles related to the Dinosaurians, but the specialized characteristics and high development of that type forbade the belief that they were in the direct line of descent. Of course the birds which agreed with the mammals in the possession of a quadrilocular heart, complete circulation, and warm blood must even more positively than the Dinosaurians be excluded from the line of descent. The problem of what was the genealogy of the highest class of animals was at last attacked by Huxley. In several memoirs,[1] published in 1876, 1879,[2] and 1880,[3] he examined the evidence and formulated his conclusions. Those conclusions were expressed in the following terms:

"Our existing classifications have no place for [the] submammalian stage of evolution (already indicated by Haeckel under the name of *Promammale*). It would be separated from the Sauropsida by its two condyles, and by the retention of the left as the principal aortic arch; while it would probably be no less differentiated from the Amphibia by the presence of an amnion and the absence of branchiæ at any period of life. I propose to term the representatives of this stage *Hypotheria;* and I do not doubt that when we have a fuller knowledge of the terrestrial vertebrata of the later palæozoic epochs, forms belonging to this stage will be found among them. Now, if we take away from the Hypotheria the amnion and the corpus callosum, and add the functional branchiæ—the existence of which in the ancestors of the mammalia is as clearly indicated by their visceral arches and clefts as the existence of complete clavicles in the ancestral Canidæ is indicated by their vestiges in the dog—the Hypotheria, thus reduced, at once take their place among the Amphibia, for the presence of branchiæ implies that of an incompletely divided ventricle and of numerous aortic arches, such as exist in the mammalian embryo, but are more or less completely suppressed in the course of its development.

"Thus I regard the amphibian type as the representative of the next lower stage of vertebrate evolution; and it is extremely interesting to

[1] On the evidences as to the origin of existing vertebrate animals. (Nature, Vol. XIII, pp. 388, 389, 410–412, 429, 430, 467–469, 514–516; Vol. XIV, pp. 33, 34.

[2] On the characters of the pelvis in the mammalia, and the conclusions respecting the origin of mammals which may be based on them. (Proc. Royal Soc., Vol. XXVIII, pp. 162, 163; Nature, Vol. XX, pp. 22–24.)

[3] On the application of the laws of evolution to the arrangement of the vertebrata, and more particularly of the mammalia. (Proc. Zool. Soc., 1880, pp. 649–662; Nature, Vol. XXIII, pp. 203, 204, 227–231.)

observe that even the existing Amphibia present us with almost every degree of modification of the type, from such forms as the oviparous, branchiate, small-lunged *Siredon* and *Menobranchus*, which stand in the same relation to it as *Gymnura* to the Eutheria, to the exclusively air-breathing Salamanders and frogs, in which the period of intraovular development, either within the uterus itself or in special receptacles, may be as much prolonged as it is in the mammalia.

"A careful study, on full materials, of the development of the young of such forms as *Hylodes* will probably throw great light on the nature of the changes which ended in the suppression of the branchiæ and the development of the amnion and of the extra-abdominal part of the allantois in the fœtus of the higher vertebrata."

During the intervening years no discoveries of fossil forms substantiating these inferences have been discovered. Among the ancient vertebrates now known none appear to be more nearly allied to the mammals than certain Permian animals representing a special order named by Cope Theromorpha or (later) Theromora. As early as 1878 "the order Theromorpha was regarded by Professor Cope as approximating the mammalia more closely than any other division of reptilia, and as probably the ancestral group from which the latter were derived."[1] These views were subsequently developed in greater detail,[2] and appear to be entitled to much consideration. In this connection it may be added that the difference between Huxley and Cope is less than the terms in which they have been stated might seem to indicate. The gap between primitive amphibians and reptiles is by no means as great as between the modern types, and it may be doubted whether the ancestors of the mammalian stock were members of the specialized order defined as Theromorpha. Neither of the philosophers may be far out of the way.

X.

Among the most important results of Huxley's investigations were the discovery and approximately correct recognition of the nature of the "peculiar gelatinous bodies" found in all the seas, whether extra-tropical or tropical, through which the *Rattlesnake* sailed, and which were named *Thalassicola*, precursors of radiolarian hosts afterwards to be brought to light, and the perception of the comparative affinities of the southern forms of astacoidean crustaceans and their contrast as a group with the forms of the Northern Hemisphere. I must resist the temptation to further enumerate the great naturalist's discoveries and generalizations.

A few words on the nature of his work may be desirable. And here it may be admitted that Huxley was rather a morphologist in a narrow

[1] The Theromorphous Reptilia. (Am. Nat., Vol. XII, pp. 829, 830, 1878.)

[2] The relations of the theromorphous reptiles and the monotreme mammalia. (Proc. Am. Assoc. Adv. Sc., Vol. XXXIII, pp. 471–482, 1 plate, 1885.)

sense, or anatomist rather than a systematist of greatly superior excellence. Unquestionably he did much excellent work in systematic zoology, but the direct subject of investigation was perhaps treated from too special a standpoint, and sometimes without an attempt to coordinate it with the results in other fields, or to measure by some given standard. He was indeed a great artist, but he used his powers chiefly to sketch the outlines of a picture of nature. This was done with the bold and vigorous hand of a master, but his productions were deficient in details and finish and were sometimes imperfect on account of inattention to perspective and perhaps deliberate neglect of the niceties of nomenclature. (And lest I may be misunderstood, let me here explain that by systematic zoology I mean the expression of all the facts of structure in a form to best represent the values of the differences as well as resemblances of all the constituents and parts of the entire organization, from the cells to the perfected organs and the body as a whole.) For example, he separated amphibians from reptiles and combined them with fishes, and yet under the last name comprised the Leptocardians and Marsipobranchs, and to his influence is doubtless due to a large extent the persistence of English (but not American) naturalists in a combination which is elsewhere regarded as contradicted by all sound morphological doctrine.[1] The value of the characters distinctive of the Rhynchocephalian reptiles and their consequent significance for taxonomy and paleontology were also denied by him. Nevertheless, even his negative position was of use in that it incited investigation. The numerous memoirs on the anatomy and characteristics of various groups of animals, too, were always replete with new facts and the hints were almost always sagacious, even if not always in exactly the right direction.

XI.

While the contest between the old and new schools of biological philosophy was at its height, the former was almost entirely supported by the religious element, and bitter were the invectives against evolution. The opposition was almost solely based on the ground that the doctrine was in opposition to revealed religion. The naturally combative disposition of Huxley was much aroused by this opposition, and the antagonism early engendered was kept aglow during his entire life. Meanwhile it had been discovered by many of the more sagacious and learned clergymen that there was no real antagonism between the scriptural account of creation and evolution, but that the two could be perfectly reconciled. The reconciliation had been effected between Genesis and astronomy and between Genesis and geology, and was continued on the same lines for Genesis and evolution. But Huxley

[1] The great English morphologists (such as Balfour and Ray Lankester), Huxley's own successor in the Royal College of Science, Professor Howes, and A. Smith Woodward among systematic ichthyologists have recognized the heterogeneity of the old class of fishes.

would have none of it. He gave expression to his convictions in the following words:

"For more than a thousand years, the great majority of the most highly civilized and instructed nations in the world have confidently believed and passionately maintained that certain writings, which they entitle sacred, occupy a unique position in literature, in that they possess an authority, different in kind, and immeasurably superior in weight, to that of all other books. Age after age, they have held it to be an indisputable truth that, whoever may be ostensible writers of the Jewish, Christian, and Mohomedan Scriptures, God Himself is their real author; and, since one of the attributes of the Deity excludes the possibility of error and—at least in relation to this particular matter—of willful deception, they have drawn the logical conclusion that the denier of the accuracy of any statement, the questioner of the binding force of any command, to be found in these documents is not merely a fool, but a blasphemer. From the point of view of mere reason he grossly blunders; from that of religion he grievously sins.

"But if this dogma of Rabbinical invention is well founded; if, for example, every word in our Bible has been dictated by the Deity, or even if it be held to be the Divine purpose that every proposition should be understood by the hearer or reader in the plain sense of the words employed (and it seems impossible to reconcile the Divine attribute of truthfulness with any other intention), a serious strain upon faith must arise. Moreover, experience has proved that the severity of this strain tends to increase, and in an even more rapid ratio, with the growth in intelligence of mankind and with the enlargement of the sphere of assured knowledge among them.

"It is becoming, if it has not become, impossible for men of clear intellect and adequate instruction to believe, and it has ceased, or is ceasing, to be possible for such men honestly to say they believe that the universe came into being in the fashion described in the first chapter of Genesis; or to accept, as a literal truth, the story of the making of woman with the account of the catastrophe which followed hard upon it, in the second chapter; or to admit that the earth was repeopled with terrestrial inhabitants by migration from Armenia to Kurdistan, little more than four thousand years ago, which is implied in the eighth chapter; or, finally, to shape their conduct in accordance with the conviction that the world is haunted by innumerable demons, who take possession of men and may be driven out of them by exorcistic adjurations, which pervades the Gospels."

So far even Huxley was not in disagreement with some of the most eminent and learned of theologians. Those of you who are interested will be able to recall utterances of enlightened clergymen which would differ from Huxley's only in the absence of the leaven of sarcasm that permeates his lines. At a late congress of the Church of England, held at Norwich, the reverend Canon and Professor Bonney gave voice to words that convey the same ideas as Huxley's.

"I can not deny," he said, "that the increase of scientific knowledge has deprived parts of the earlier books of the Bible of the historical value which was generally attributed to them by our forefathers. The story of the creation in Genesis, unless we play fast and loose either with words or with science, can not be brought into harmony with what we have learned from geology. Its ethnological statements are imperfect, if not sometimes inaccurate. The stories of the flood and of the Tower of Babel are incredible in their present form. Some historical element may underlie many of the traditions in the first eleven chapters of that book, but this we can not hope to recover."

But Huxley was not content to deny any authority to the Scriptural basis of most of the religions of Europe and America. He denied that there was any means of knowing what the future had in store. He did not deny that there was a heaven or a hell; he did not deny that in a future world man might continue in a sublimated state, and might be punished for his misdeeds or rewarded for the good deeds he had performed and for good thoughts on earth. He did not venture to express any opinion on the subject for the reason that he had no data to base an opinion upon. He called himself an agnostic and the attitude he assumed was agnosticism.

This term agnostic, we are told by Mr. R. H. Hutton, was suggested by Professor Huxley at a party held previous to the formation of the now defunct Metaphysical Society, at Mr. James Knowles's house on Clapham Common, one evening in 1869, and was suggested by St. Paul's mention of the altar to the unknown God—Ἀγνώστῳ θεῷ.

But Huxley has explained that he assumed this term in contradistinction to the gnostic of old. The gnostic claimed to know what in the nature of things is unknowable, and as Huxley found himself with an exactly opposite mental status, he coined a word to express that antithetical state—agnostic.

I have done all I conceive to be necessary in giving this statement of Huxley's attitude. Whether he was right or wrong, each one must judge for himself or herself. Believing as he did, on a bed of prolonged illness he resignedly awaited the inevitable, and desired that his sentiments reflected in verse by his wife should be engraved on his tomb.

"And if there be no meeting past the grave,
If all is darkness, silence, yet 'tis rest.
Be not afraid, ye waiting hearts that weep,
For God 'still giveth his beloved sleep,'
And if an endless sleep he wills—so best."

PASTEUR.[1]

By George M. Sternberg, M. D., LL. D.,
Surgeon-General, United States Army.

Ladies and Gentlemen: I am to speak to you of the life and achievements of one who has won imperishable renown by his valuable contributions to human knowledge, and who has recently been buried in the city in which his scientific labors have been prosecuted, with all the honors which it was possible for a grateful people to confer. It is certainly a happy augury for the future when the man of science, whose achievements have been the result of painstaking and laborious work in the laboratory, receives the grateful plaudits of his fellow-men during his lifetime and the honors which were formerly only paid to civil potentates or military heroes when his body is committed to the tomb. It has been the fortune of few men to contribute so largely to the sum of useful knowledge, and fewer still have lived to receive such ample recognition of the value of their scientific work.

Pasteur's success has been due to a combination of personal qualities which especially fitted him for the pioneer work which he has done in his chosen field of scientific investigation. With that penetrating intellect and versatility of resource which constitutes genius, was combined an energy and persistence of purpose, a disregard of accepted theories not supported by evidence, and an appreciation of the value of the experimental method as the only reliable means of arriving at exact truth. No amount of conservative opposition intimidated him when he announced results obtained by his carefully conducted laboratory experiments, and no false pride seduced him into maintaining a position which he had once taken, if the experimental evidence was against him. This rarely happened. But where is the man of science who is infallible? Working in a new field, by methods largely of his own devising, which were necessarily more or less imperfect at the outset, it is surprising how few mistakes he made.

With his genius for scientific research, his indomitable perseverance, and the forceful character which enabled him to defend his discoveries

[1]Memorial address delivered January 14, 1896, under the auspices of the Joint Commission of the Scientific Societies of Washington. Reprinted from Science. New series, Vol. III, No. 58, February 7, 1896.

so successfully, there must have been associated a kindly disposition, for those who were closely associated with him in his laboratory work were devotedly attached to him. He evidently had the faculty of inspiring others with his enthusiasm for science, and their loyalty to him and to their common mistress was rewarded by the frank acknowledgment on his part of their share in the work accomplished. So far as I am aware, he never showed any disposition to appropriate for himself credit due to another, whether that other was an associate or pupil in his own laboratory, or one who was prosecuting his investigations elsewhere. The speaker's personal acquaintance with Pasteur is limited to a memorable half day spent in his laboratory about ten years ago. Although still disabled to some extent by paralysis, resulting from his first apoplectic attack, he conducted me through his laboratory and with the greatest kindness explained to me the methods in use and the results recently accomplished in the lines of experimental work which at that time occupied the attention of himself and his colleagues.

The time at my disposal will permit only a brief review of the life and work of this illustrious savant; but this review will show that his scientific achievements are of the highest order, and that the practical benefits resulting from his labors have extended to all parts of the civilized world. He belongs not alone to France, but to science, and it is eminently fitting that we should pay a tribute to his memory in this capital city of a country in which his name is so well known and in which the results of his scientific investigations are so highly appreciated.

Louis Pasteur was born at Dôle, a small town in the Department of Jura, France, on the 27th of December, 1822; he died at his home in Garches, a suburb of Paris, on the 28th of September, 1895.

Pasteur's father had been a soldier in the army of Napoleon, but at the time of his famous son's birth was working at his trade as a tanner. In 1825 the family moved to Arbois, a small town in the same department, and here Louis Pasteur attended school at the collège communal. Later he was sent to the college at Besançon, where he took his degree of Bachelier des Lettres. He subsequently entered the École Normale of Paris, and while there devoted himself to his favorite study—chemistry. Three years after joining the École Normale he was appointed assistant professor of physical science. In 1848 he was appointed professor of physics at Dijon, and after a few months resigned his position for the chair of chemistry in the University of Strasburg. In 1854 Pasteur was induced to accept the position of dean of the newly created Faculty of Sciences at Lille, and in 1857 he returned to Paris as scientific director of the École Normale, where he had gained his first scientific laurels. In 1862 Pasteur became a member of the Institute, and in the same year he was appointed professor of geology, physics, and chemistry in the École des Beaux Arts. He was elected to the Academy of Sciences, taking the Fauteuil of Littré, in 1881. The same year

he received the Grand Cross of the Legion of Honor. In 1874 the National Assembly of France voted him a life pension of 20,000 francs annually. Upon the anniversary of his seventieth birthday, December 27, 1892, he received from his compatriots a superb ovation at the Sorbonne, which was attended by President Carnot, the members of the French Institute, all foreign ministers and ambassadors then at the French capital, and delegates from scientific societies in all parts of the world. The Pasteur Institute, established in his honor, was inaugurated with proper ceremonies on the 14th of November, 1888. It is situated in the rue Dutot, Paris, and is an imposing stone building in the style of Louis XIII. It was built and equipped from a fund raised by public subscription, amounting to 2,586,000 francs. Of this sum 200,000 francs was voted by the French Chambres Legislatif. After the completion and equipment of the building more than 1,000,000 francs remained as a permanent endowment.

The time at my disposal will permit of but a brief review of Pasteur's scientific achievements. After having made some notable discoveries in chemistry his attention was attracted to the minute organisms found in fermenting liquids, and by a brilliant series of experiments he demonstrated the fact that the chemical changes attending fermentation are due to the microscopic plants known as bacteria; also that different species give rise to different kinds of fermentation, as shown by the different products evolved during the process. In prosecuting these studies he discovered the species which produce lactic acid, acetic acid, and butyric acid, and he added largely to our knowledge relating to alcoholic fermentation and the class of micro-organisms to which it is due. He showed that in the absence of living organisms no putrefaction or fermentation can occur in organic liquids, and that these low organisms do not develop by spontaneous generation, as was at that time generally believed, but have their origin from preexisting cells of the same species, which are widely distributed in the atmosphere, especially near the surface of the earth. Various experimenters had shown that a development of bacteria sometimes occurs in boiled organic liquids excluded from the air. Pasteur showed that this was not due to spontaneous generation, but to the survival of the spores of certain species of bacteria. These are able to resist a boiling temperature without loss of vitality and reproductive power.

In 1865 the distinguished French chemist Dumas invited his former pupil, Pasteur, to make investigations with reference to the cause and prevention of a fatal malady among silkworms, which threatened to destroy the silk industry of France. In the course of an investigation which occupied several years, Pasteur succeeded in demonstrating the nature of the infectious malady known as pébrine, the mode of its transmission, and the measures necessary to eradicate it. Following his advice the growers of silkworms succeeded in banishing the scourge, and within a few years the industry was reestablished upon its former profitable footing.

This pioneer work led to further investigations with reference to the cause and prevention of certain infectious diseases of the lower animals, and especially to the fatal disease of cattle and sheep known as anthrax. Having satisfied himself that this disease is due to a bacillus, which is found in great numbers in the blood of infected animals, he demonstrated by experiment that this bacillus rapidly loses its virulence when cultivated in artificial media at a temperature of 42° to 43° C. Also that animals inoculated with this "attenuated" virus suffer a mild attack of the disease, and that after their recovery they are immune against future attacks, even when inoculated with the most virulent material. This discovery has been applied practically, on an extensive scale, in France, Austria, Switzerland, and other European countries. The result of anthrax inoculations made by Pasteur's method in France during the past twelve years was summarized by Chamberland in 1894. He reports the total number of animals inoculated during this period as 1,788,677 sheep, and 200,962 cattle, and estimates the total saving as the result of the inoculations as 5,000,000 francs for sheep and 2,000,000 francs for cattle.

Another infectious disease in which Pasteur's method has been employed with success is rouget or hog erysipelas. Chamberland states that as a result of the protective inoculations practiced with Pasteur's vaccines the mortality from this disease in France has been reduced from about 20 to 1.45 per cent. Hutyra reports that during a single year (1889) 48,637 pigs were inoculated with Pasteur's vaccines in Hungary with a loss of 0.29 per cent, while the losses upon the same farms in previous years averaged from 10 to 30 per cent.

But we must pass to that portion of Pasteur's scientific work which has most engaged the attention of the public. Pasteur first announced his success in reproducing hydrophobia in susceptible animals by inoculations of material obtained from the central nervous system in a communication made to the Academy of Sciences on May 30, 1880. Continuing his investigations he reported, in 1884, his success in conferring immunity against hydrophobia in nineteen dogs inoculated, in the presence of a commission appointed for the purpose, as a test experiment. These animals had been rendered refractory by his method. The nineteen protected animals and nineteen control animals obtained from the public pound without any selection were tested at the same time. The test was made upon some of the animals of both series by inoculation with virulent material upon the surface of the brain, and upon others by allowing them to be bitten by rabid dogs, and upon still others by intravenous inoculations. Not one of the protected animals developed hydrophobia; on the other hand, three of the control animals out of six bitten by a mad dog developed the disease, five out of seven which received intravenous inoculations died of rabies, and five which were trephined and inoculated on the surface of the brain died of the same disease.

With reference to his first inoculations in man, Pasteur says:

"Making use of this method, I had already made fifty dogs of various races and ages immune to rabies, and had not met with a single failure, when, on the 6th of July, quite unexpectedly, three persons, residents of Alsace, presented themselves at my laboratory."

These persons were Theodore Vone, who had been bitten on the arm on July 4, Joseph Meister, aged 9, bitten on the same day by the same rabid dog, and the mother of Meister, who had not been bitten. The child had been thrown down by the dog and bitten upon the hand, the legs, and the thighs, in all in fourteen different places. Pasteur commenced the treatment at once, and had the satisfaction of reporting to the Academy of Sciences in March of the following year (1886) that the boy remained in perfect health. Since this time Pasteur institutes for the treatment of hydrophobia have been established in all parts of the civilized world, and the statistical reports published justify the belief that when the treatment is instituted at an early date after the bite, and is properly carried out, its protective value is almost absolute. At the Pasteur Institute in Paris, 9,433 persons were treated during the years 1886 to 1890, inclusive. The total mortality from hydrophobia among those treated was considerably less than 1 per cent (0.61). In 1890, 416 persons were treated who had been bitten by animals proved to be rabid, and among these there was not a single death. In 1891 the number of inoculations was 1,539, with a mortality of 0.25 per cent; in 1892, 1,790, with a mortality of 0.22 per cent; in 1893, 1,648, with a mortality of 0.36 per cent; in 1894, 1,387, with a mortality of 0.50 per cent.

There has been and is still a considerable amount of skepticism among members of the medical profession and others as to the practical value of Pasteur's inoculations for the prevention of hydrophobia; and some physicians have even contended that the disease known by this name is not the result of infection from the bite of a rabid animal, but is a nervous affection due to fear. The time at my disposal will not permit me to present for your consideration the experimental and clinical evidence upon which I base the assertion that nothing in the domain of science is more thoroughly demonstrated than the fact that there is a specific infectious disease known to us as rabies, or hydrophobia, which may be communicated to man, or from one animal to another, by the bite of a rabid animal, and that Pasteur's inoculations prevent the development of the disease in animals which have been infected by the bite of a rabid animal or by inoculations with infectious material from the central nervous system. This being the case, it is evident that there is a scientific basis for Pasteur's method of prophylaxis as applied to man, and his published statistics give ample evidence of the success of the method as carried out at the Pasteur Institute in Paris and elsewhere. Great as have been the practical results which have already followed Pasteur's brilliant discoveries,

there is reason to believe that in the future still more will be accomplished, especially in combating the infectious diseases of man. Having pointed out the way, a multitude of earnest investigators in various parts of the world are now engaged in laboratory researches relating to the cause, prevention, and cure of infectious diseases. Already, in the treatment of diphtheria and of tetanus with blood serum obtained from immune animals, results have been obtained of the highest importance, and it seems probable that in the near future other infectious diseases will be cured by a specific treatment based upon scientific information obtained by those who have been following in the pathway marked out by Pasteur, the illustrious pioneer in this line of research.

HELMHOLTZ.[1]

By T. C. MENDENHALL.

Hermann Ludwig Ferdinand, Baron von Helmholtz, was born in Potsdam on August 31, 1821. In 1842 he received his degree in medicine at Berlin, and entered the Government service as an army surgeon. In 1847 he published his essay on the Conservation of Energy. In 1849 he was appointed professor of physiology at Bonn. In 1851 he invented the ophthalmoscope. In 1855 he was made professor of anatomy and physiology at Bonn. In 1859 he was appointed to the same chair at Heidelberg. In 1860 he was made one of the foreign members of the Royal Society of London. In 1863 he published his great work on the Sensations of Tone. In 1866 the first edition of his Physiological Optics was completed. In 1871 he was made professor of natural philosophy at the University of Berlin. In 1873 he received from the Royal Society the highest distinction which it can bestow, the Copley Medal; and in the same year the King of Prussia conferred upon him the Order of Merit in Science and Art. In 1883 hereditary nobility was conferred upon him by Emperor William I. In 1887 he assumed the directorship of the great Physico-Technical Institute, founded by the German Government at Charlottenberg. In 1891 the seventieth anniversary of his birth was celebrated with great ceremony, and he was placed at the head of the civil list by the German Emperor. In 1893 he visited America, serving as president of the International Electrical Congress held in Chicago. In 1894, on September 8, he died at the age of 73 years.

Such is the brief outline of the life of one of the most extraordinary men of the present century. To perfect such a sketch in anything like just proportions, or to attempt in the few minutes allotted to me to-night to set forth anything like a fair estimate of the labors of one of whom it may be justly said that he was the most accomplished scholar of modern times, is a task no one would seek. Nor can one easily decline the honor which is carried by an invitation from a commission representing the scientific societies of Washington to take part in so memorable a commemoration as this. Under the circumstances, I must

[1] Read at a memorial meeting under the auspices of the Joint Commission of the Scientific Societies at Washington City, January 14, 1896. Reprinted from Science. New series, Vol. III, No. 58, February 7, 1896.

confine myself to an exposition, all too brief, of a few only of the principal contributions to human knowledge among the great number for which the world is indebted to Professor Helmholtz. It was his distinctive characteristic that among the exponents of modern science he stood quite alone in being really great along several lines. He was in the beginning and always a pure mathematician of high type. Anatomists and physiologists claimed him for their own. During a few days' stay in New York in 1893, after having presided over the International Congress of Electricians, he was entertained by a distinguished surgeon, the leading eye specialist of the country, and ophthalmologists flocked to do him honor as one of the founders of their profession. When, in 1881, he gave the Faraday lecture before the Chemical Society of London, the president of the society in presenting to him the Faraday Medal, declared that eminent as was Helmholtz as an anatomist, a physiologist, a physicist, and a mathematician, he was distinctly claimed by the chemists. Nor were these only idle compliments. Only a few days ago I happened on a most curious and interesting illustration of the unequaled extent of his scientific constituency in finding, in a widely known journal published in London, his obituary notice indexed under the heading, "The stage and music," where his name appeared accompanied by only that of Anton Rubenstein. His great work on the Sensations of Tone and his analysis of the vowel sounds of the human voice gave him a lasting fame among musicians.

Psychology as well as æsthetics was benefited by his touch, but I think it will be generally admitted that he was first of all, and more than all else, a physicist. Indeed, it may be said that the best fruits of his study of other branches of science grew out of the skill with which he ingrafted upon them the methods of investigation for which we are primarily indebted to the physicist.

When a boy he had acquired a fondness for the study of nature. His father was a professor of literature in the gymnasium at Potsdam; his mother a woman of English descent. Although he was encouraged in the development of his youthful tastes as much as possible, the necessity for earning a living directed his professional studies toward medicine and he became a military surgeon. As a physiologist, he was led to the study of "vital force;" his taste for mathematics and physics forced him to the dynamical point of view, and his first great paper, prepared before he was 26 years of age, was on the Conservation of Energy. It is now nearly fifty years since this essay was presented to the Physical Society of Berlin, and doubtless quite fifty years since it was actually worked out. Its excellence is shown by the fact that if rewritten to-day it would be changed only a little in its nomenclature. Fifty years ago the great law of the conservation of energy, which will ever be regarded as the most pregnant and far-reaching generalization of this century, was so far from being known or recognized that many of the ablest men of the time either regarded it as a "fanciful speculation"—or did not regard it at all.

As a matter of ordinary mechanics, it had long been admitted that no machine could create power, and as a part of that applied was always lost or frittered away in friction the work coming out of a machine must always be less than that put into it. The first great advance had been made by an American, Benjamin Thompson, afterwards Count Rumford, when he asked what became of that part lost in friction and found his answer in the heat generated thereby, thus proving that "heat was a mode of motion" rather than an "imponderable agent," as it was rather ambiguously designated up to nearly the middle of this century, but that all of the forces of nature were so related to each other as to be interconvertible, and that the sum total of all the energies of the universe was always the same, energy being no more capable of creation or destruction than matter; these were great facts, mere glimpses of which had been permitted to the physicists of the early part of the century. Helmholtz was certainly one of the first to completely grasp this splendid generalization, and not more than two or three others stand with him in the credit which is due for its complete proof and general acceptance. His first contribution had the merit of being quite original in conception and execution, for he then knew almost nothing of what others had done; he was entirely ignorant of the important paper of his fellow-countryman, Mayer, and knew only a little of Joule's earlier work. The principle of the conservation of energy, which for a quarter of a century has been the open sesame to every important advance in physical science, was not then, to say the least, a popular topic. But for five or six years a young Englishman named Joule, not yet 30 years old, had been engaged with it and, from the point of view of the engineer, had made it his own. On the 28th of April, 1847, he gave a popular lecture in Manchester, where he lived and died, which was the first full exposition of the theory. A few weeks later Helmholtz read his paper in Berlin. In England, even the local press refused to publish Joule's address, but finally the Manchester Courier, moved by the family influence (the elder Joule being a wealthy brewer), promised to insert the whole as a special favor. In Germany the subject met with only a little more favorable reception, and the leading scientific journal, Poggendorff's Annalen, declined to publish Helmholtz's paper. Even at the meeting of the British Association at Oxford a few months after the Manchester address, when Joule again undertook the exposition of his theory and his experimental proofs of it before what ought to have been a more friendly audience, he was advised by the chairman to be brief, and no discussion of his paper was invited. As Joule himself relates, his presentation of the subject would have again proved a failure "if a young man had not risen in the section and by his intelligent observations created a lively interest in the new theory." This young man was William Thomson, then 23 years old, now Lord Kelvin, the foremost of living physicists.

The tremendous blows struck by Helmholtz in support of the new

doctrine, from that time until it was no longer in the balance, give evidence alike of his extraordinary talents and his fine courage. The publication of this important essay in 1847 had also the effect of bringing about an immediate appreciation of his abilities. Du Bois-Reymond gave a copy of it to Tyndall, then a student of Magnus in Berlin, saying that it was the product of the first head in Europe. He was shortly removed to the more favorable environment of a university professorship at Königsburg. During the next twenty years he advanced from Königsburg to Bonn, from Bonn to Heidelberg and from Heidelberg to Berlin. While it was only on reaching the University of Berlin that he assumed his true function of professor of physics, yet the previous two decades had been rich in the application of physical methods to physiological subjects.

In 1863 he published the remarkable monograph on the Sensations of Tone. This work is a most masterly analysis of the whole subject implied in its title and must always remain a classic. Only one or two of the most important results of the profound researches of the author can be referred to here. As everyone knows, the character of a musical tone is threefold. There is first its pitch, which has long been known to depend upon the frequency of vibration of the string or reed, or whatever gives rise to the sound; there is next the loudness, which depends upon the amplitude of this variation, or, in a general way, on the energy expended by the vibrating body. But two tones may agree in pitch and in loudness and still produce very different impressions on the ear. It is this which makes it possible to know when a musical tone is heard that it comes from an organ, or a flute, or the human voice. It enables an expert to know on hearing a single note from a violin that the instrument was made in a given year by a certain artist; by virtue of this characteristic one instantly recognizes a voice which one has not heard for many years as belonging to a particular individual.

So little was known of the physical cause of this inherent peculiarity of a sound that for many years it went unnamed. Helmholtz called it the "Klangfarbe;" literally, "tone color;" but in English the term "quality" is now universally applied to it. What is the physical cause of the quality of a tone is the question the answer to which he sought. All that there is in a tone, he said—pitch, intensity, and quality—must be borne upon the air waves by which the sound is communicated to the ear, and all that these waves bear must be impressed upon them by the vibrating body in which the sound originates. He did not fail to recognize, however, and this was extremely important, that there might exist peculiarities in the receiving instrument, the ear (through the operation of whose mechanism the motion of matter is interpreted as a sensation), the existence of which would materially modify the final outcome, to the end that two physically identical tones might give rise, under certain circumstances, to different sensations. Guided by these principles, he discovered that the quality of a tone, that characteristic

which gives charm to it, was really due to its impurity; that if two perfectly pure tones, generated by simple, pendular vibrations, agreed in pitch and loudness, it would be quite impossible to distinguish them. But practically, such tones are never produced; all ordinary tones are composite, made up of the fundamental, which generally fixes the nominal pitch of the whole, and a series, more or less complete and extended, of overtures or harmonics, the vibration frequencies of which are two, three, four or some other multiple of that of the fundamental. Without these, the fundamental, though pure, was plain, dull, and insipid; with them it formed a composite with quality, soft it may be, or brilliant, or rich, or harsh, or any of the thousand things which may be said of a tone. Which it was and what it was, was determined by the relative proportions of the several overtones, indefinite in number, in the composite whole. This beautiful hypothesis was illustrated and established by innumerable experiments, and it was proved that the form of the air wave was the quality of the tone, and that this form originated in the mode of vibration of the sounding body, which was almost universally not simple, but complex. But the most important work of Helmholtz along this line was the extension of this theory to the solution of a problem more than two thousand years old, proposed, in fact, by the Greek, Pythagoras. It meant nothing less than the physical explanation of harmony. Why are certain combinations of musical tones agreeable and others unpleasant? And, indeed, the answer to this tells as well why a certain succession of tones, as in a musical scale, is likely to be generally acceptable to the human ear. Lack of time will only permit me to say that in the interference and consequent beating of certain of the overtones or upper partials of two fundamentals, Helmholtz found the explanation of their dissonance, and that while in certain particulars his theory as originally published has been criticised, it is in general universally accepted and admitted to be one of the most splendid contributions to modern science.

I am warned, also, that I must not speak of that other great work, the Physiological Optics, as I would so gladly do if time permitted. Helmholtz was actually engaged in the preparation of this and the Sensations of Tone during the same years. No other man in the world could have written these, for no other was at once an accomplished physiologist, mathematician, and physicist. While I can not speak of his contributions to the science of optics and ophthalmology, I must not omit brief reference to his invention of the ophthalmoscope and the ophthalmometer. Anxious to actually see what goes on in the eye, and especially on the retina, that wonderful screen on which the image of the visible world is focused, he invented the ophthalmoscope. The qualitative victory was followed by the quantitative in the invention of the ophthalmometer, by means of which accurate measurements of the various curved surfaces in the eye could be made. These two instruments have been to ophthalmic surgery what the telescope and graduated circle have been to astronomy. So exact has the science of the

eye become through their use that it is not great exaggeration to say that one may now have a disordered eye repaired, corrected, and set going with little more uncertainty than attends the performance of the same duty for an ill-conditioned chronometer. Had Helmholtz accomplished nothing except the invention of these instruments, he would have been entitled to the thanks of all mankind, on account of the comfort they have added to life and the pain and suffering they have prevented.

If I had devoted all of the time allotted to me to a simple enumeration of the contributions to human knowledge made by Von Helmholtz during fifty years of marvelous intellectual activity, I must have left my task incomplete; but I must not close without reference to one or two of these, more purely physical in their character and equally stamped with the genius of their author.

Perhaps Nature has shown herself most reticent and unyielding when scientific men have questioned her as to the ultimate structure of matter, the full knowledge of which includes a satisfactory explanation of the force of gravity, which is one of its essential properties. Hypotheses which have been very useful in their time have been finally rejected because they involved some impossible conception, such as action at a distance, which was for a long time believed possible. The tendency is now and has long been to regard space, or at least that part of it in which we have any particular interest, as a plenum, and to assume a continuous, incompressible, frictionless elastic fluid in which and of which all things are. In the development of his exquisite theory of vortex motion, Helmholtz demonstrated the possibility of a portion of such a fluid being differentiated from the rest in virtue of a peculiar motion impressed upon it, and that when so differentiated it must forever remain so, a fact which was quickly seized upon by Lord Kelvin as the foundation of a vortex theory of matter, thus sharing with Helmholtz the honor of having approached nearer than all others to the solution of the great mystery.

From the genesis of an atom to the origin of the universe seems a long step, but it is not too great for the intellect of man. The well-known nebular hypothesis was advanced long before Helmholtz's time, but a better knowledge of thermodynamics had quite upset one of its generally accepted principles, namely, that the original nebulous matter was fiery hot. As long ago as 1854, Helmholtz showed that this was not a necessary assumption, and proved that mutual gravitation between the parts of the sun might have generated the heat to which its present high temperature is due. The greatest philosophers of the past hundred years have attempted to account for this high temperature and for its maintenance, on which all life on this globe depends. The simple dynamical theory of Helmholtz has survived all others, and is to-day universally accepted.

But I must cut short this absolutely inadequate account of what the scholar did, that I may say a word or two of what the man was.

Although one of the most modest and quiet of men, no one could meet him without feeling the charm of his personality. While he bore a dignity which became the great master of science which he was everywhere admitted to be, he was approachable in an extraordinary degree. He was eloquent in popular address and believed in the obligations of men of science to the general public. In scientific discussion, whether on his feet or with pen in hand, there was a certain massiveness about his style and manner which was generally irresistible. In his attacks upon the region of the unknown he showed possibly less brilliant strategy than one or two of his contemporaries, but he rarely, if ever, found himself obliged to conduct a retreat. In 1893 he was selected by the Emperor as the head of the German delegation, five in number, to the International Electrical Congress held in Chicago in August of that year. His more than three score and ten years weighed upon him, and he begged to be relieved of the duty. The young Kaiser, who was fond of him and who loved to honor him in every way, sent for him. On hearing his modest plea, he said, "Helmholtz, you must go; I want the Americans to see the best I have of every kind, and you are our greatest and best man." As becomes a dutiful subject he yielded. While in this country every honor was shown him. Here he found many of the hundreds and thousands of his pupils who everywhere in the world are adding luster to his name by perpetuating his spirit and his methods, and all were ready to serve him. Electrician, mathematician, physiologist and physicist, he found everywhere a large and appreciative constituency, while his own almost boyish pleasure in whatever he saw that was novel, was charming to see.

On his homeward voyage he met with an accident which was thought by many to be the beginning of the end. Up to the time of his death, which occurred about a year later, he continued, but not very actively, to direct the great institution for original research, in which, by the wisdom of an appreciative Government, he had found full scope for his powers. His interest in the important work done at the Chicago Congress continued through this year, and one of the few long letters he wrote had reference to its proceedings. On the 8th of September, 1894, he died, and on the 13th he was buried at Charlottenberg, princes and peasants alike mourning his loss.

Von Helmholtz occupied so large a part of the scientific horizon and for so long a time that we have not yet become accustomed to his absence. But it is not too soon to agree that the following admirable lines which appeared in the London Punch a little more than a year ago express in some measure our judgment of the man and his work:

> "What matter titles? *Helmholtz* is a name
> That challenges alone the award of fame!
> When Emperors, Kings, Pretenders, shadows all,
> Leave not a dust-trace on our whirling ball,
> Thy work, oh grave-eyed searcher, shall endure,
> Unmarred by faction, from low passion pure."

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